(III) #1 Groundwater
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PROCEEDINGS

1965 BIENNIAL CONFERENCE ON

GROUND WATER

RECHARGE, DEVELOPMENT AND MANAGEMENT

Edited by

LEONARD SCHIFF

THEME: The best policies and practices will result when legislators, administrators, engineers, attorneys, agriculturists, economists, political scientists and other interested people develop action programs based on mutual understanding.

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1965 BIENNIAL CONFERENCE ON GROUND WATER

RECHARGE, DEVELOPMENT, AND MANAGEMENT

UNIVERSITY OF CALIFORNIA
LOS ANGELES
SEPTEMBER 1-2, 1965

EDITED BY

LEONARD SCHIFF

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1965 BIENNIAL CONFERENCE ON GROUND WATER

RECHARGE, DEVELOPMENT, AND MANAGEMENT

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WELCOME

Foster H. Sherwood, Vice-Chancellor
University of California, Los Angeles

Your presence at this Biennial Conference on Ground Water -- Recharge, Development, and Management is witness to the fact that this is not a problem that is limited to Southern California. Notice in your program the representatives from the West and indeed, from beyond the limits of the United States. But I think it fair to say that we in the West have been more conscious of the problems of water and its uses from the very beginning of our existence, since natural resources in general and water in particular have been so important to our development. As a consequence, I think it likewise fair to say that the Western States have moved more imaginatively and vigorously in dealing with these problems. Again, I would point to the continuing growing interest evidenced by your presence here today.

But as the work in the area of water management has developed, it has become increasingly evident that this is not just a problem in engineering. Law and government and economics are all bound up with the engineering aspects of this problem, and the juxtaposition of these disciplines are recognized in your program and in the work you will be doing today and tomorrow.

A recent estimate from the United States Department of Agriculture indicates that as of about 1960, we had a capital investment in water resources in this country of approximately $180 billion, and we should look forward in the next generation to an additional expenditure of well over $225 billion. The size of these figures and the fact that they are put in dollars, indicates that economics and government are going to play key roles in this development. So it is appropriate that this meeting be held in the West. It is appropriate that this meeting be held in Southern California. It is particularly appropriate that this meeting be held on the campus of a university. In this university are respresented substantially all of the disciplines that must contribute to the resolving of the problem of water management and use and as an urban university it is perhaps more closely in touch with the critical aspects of these problems. And finally, a university which by its charter and by its performance are dedicated to public service and public programs. Thus, it is appropriate that we meet here today, and for these reasons I welcome you and give you best wishes for a most successful meeting, for I am sure that your success will contribute not only to the community's welfare, but to the University's welfare as well.

The rather broad context in which these problems must be looked at are wonderfully illustrated in the chairman who will preside at this morning's session. Assemblyman Carley Porter, who has represented the 38th District in the California Assembly since 1949, has a background which particularly qualifies him for dealing with these problems. His official biography indicates that he taught history for some time at Long Beach City College. He apparently decided in the 1940's that rather than teach it he would start to make it, and having run and been elected to the California Assembly, he has carried on one of those multifaceted careers that is certainly to be admired. He has been involved

throughout that career in business, in education, in civic affairs of every imaginable kind. He presently served as a member of the Assembly Committee on Agriculture, the Assembly Committee on Military and Veterans Affairs, and is a member of the Committee on Ways and Means. Since 1959 he has served as Chairman of the Assembly Committee on Water. He is also chairman of a Subcommittee of the Ways and Means Committee on Agriculture, Natural Resources and Water Resources, and is a member of the Joint Assembly Senate Committee on Water Problems. For many years he has served as elected chairman of the Los Angeles delegation to the California Legislature. He is coauthor of the Burns-Porter Act of 1960, which when approved by the voters in that year, started the Feather River Development Program. But in addition to this obvious emphasis upon water problems in California, Assemblyman Porter has been active in school, agricultural affairs, has been responsible for considerable legislation affecting local government, criminal law, the dairy industry--the list is almost endless. But today is a special occasion in the career of Assemblyman Porter, for it represents the fourth anniversary of the passage of the Porter-Dolwig Act of 1961, and we now may in retrospect examine that legislation and its effects, and in prospect to anticipate the changes that it will bring about. In commemoration of this event, it is my pleasure to call on Mr. Reginald C. Price, the Deputy Director for Policy of the State Department of Water Resources, who will present a tribute to Assemblyman Porter on this, the fourth anniversary of the Porter-Dolwig Act.

1965 BIENNIAL CONFERENCE ON GROUND WATER -- RECHARGE, DEVELOPMENT, AND MANAGEMENT UCLA, SEPT. 1-2

CONFERENCE OBJECTIVES

Leonard Schiff
Program Chairman

On behalf of all participants I thank you, Chancellor Sherwood, for your welcome to UCLA. I also thank all at UCLA who are hosts to participants, who are making facilities available, and who are adding their helpful personal touch to this Conference.

It is encouraging to see the growth of this Conference and to see several hundred people from various states, of outstanding talent and interest in the important field of water, assemble to discuss recharge, development, and management of ground water in this the major conference of its kind in the United States. We are especially indebted to the 100 or so people who have come here from other states and other countries to share their experiences with us and to contribute to the proceedings. I quote from a letter to me dated July 1, from Governor Brown: "Thank you for sending me the program and other information on the Biennial Conference on Ground Water to be held on September 1 and 2.

I have been very hopeful it would be possible for me to participate in this important conference. Unfortunately, in firming up my September calendar, I now find I cannot be with you, and I am extremely disappointed.

Please convey my greetings and sincere best wishes to all assembled for a highly productive and successful conference."

I take the liberty of quoting from portions of another letter to me dated April 22: "Thank you very much for your recent letter to me inviting me to participate in the 1965 Biennial Conference on Ground Water. I appreciate very much the opportunity to participate in this program, as I have enjoyed very much participating in the fine work that these Conferences have done in previous years. I will be pleased to serve as a presiding officer, I will also be pleased to prepare a statement on ground water. Finally if the audience has not tired of me by that time, I will be happy to serve on the panel on the final afternoon. I will be in touch with you and appreciate again the opportunity to participate in this program." As Program Chairman of a conference of this magnitude with its many details I can tell you that such a letter is very encouraging and stimulating. This letter was written by the man we are honoring today for his many contributions in the field of water and to the public - Carley Porter. He has encouraged and supported this Conference over the years. May I suggest that we also honor him for his spirit of cooperation, so well exemplified by his letter, and for his desire to serve and build. He brings to this field knowledge, integrity, desire and action.

In thinking of people who have helped build this Conference I think of P. H. McGauhey, Director of the Department of Engineering, University of California, Berkeley, who has contributed much to this Berkeley-based Conference; William Berry, former Chief of the Division of Resources Planning, California Department of Water Resources, now leader of the water phase of the Chile-California Mission; Joyce Peters, Senior Engineer in the Division of Resources Planning, California Department of Water Resources; Harvey Banks, President, Leeds, Hill and Jewett, Inc., Consulting Engineers; and James Krieger, Attorney, with Best, Best and Krieger, Attorneys at Law.

This Conference has been brought south to UCLA this year at the invitation of Warren Hall, Director, Water Resources Center, and Albert Bush and Arthur Pillsbury of the Engineering Department. Details here have been so ably handled by Sam Houston, Head of Engineering Extension, and his administrative assistant Betty Leventhal.

There is a person, who in addition to meeting regular full time duties has taken care of many details of this Conference for me, the considerable correspondence, the collection of information and the handling and mailing of invitations. A person who works with ambition, drive, and courtesy to faithfully serve the public. Ladies and gentlemen this person has earned our admiration. Mary Starry will you please stand up. On behalf of sponsors and participants I thank you Mary.

There is probably no panacea for water resource problems. Cloud seeding may play a part, evaporation suppression will help, and salt water reclamation will find a place. Also, it would be a mistake to overlook the powerful potential of nuclear energy. Probably no hydrologic magic or even ample supplies of water envisioned under such plans as the North American Water and Power Alliance will substitute for the scientific collection of hydrologic data and for sound, hydrologic, coordinated management of our surface and ground water. Conservation and management of our <u>accumulated reserve -- ground water</u> -- will be one of the critical factors in development. Maximum and efficient use of each unit of water is a major challenge in a growing society.

The theme and premise of this Conference is "The best policies and practices will result when Legislators, Attorneys, Administrators, Engineers, Agriculturists, Economists, Political Scientists, and other interested people develop action programs based on mutual understanding." Men in these fields should seek understanding with each other and with the public and press. Technical approaches must be tempered by social and economic considerations. On the broadest level it appears that efficient and economical practices will come as a result of comprehensive watershed planning for the conservation of our natural resources under the cooperative endeavors of people from local to regional areas in towns, cities, states and at the national level. This can be attained by working together in understanding.

As Program Chairman, I am grateful to the presiding officers, moderators, speakers, and all attendees who are giving time to get together in complete cooperation under the philosophy expressed in the theme. Speakers have been asked to talk in popular language to help attain understanding.

If I were to pick a principal objective of this Conference it would be for each of you to become a part of this Conference -- to ask questions, to express your opinion and ideas whether or not they are in agreement with previously expressed opinions. If I had to pick a popular name for this Conference I would call it the People's Conference on Water, your Conference. The theme can only come to life through you.

The promotion of action programs will be the subject and object of the concluding Conference summary panel listed as "How Do We Meet Needs and Accelerate Action." Moderators and some of the speakers have been asked to serve on this panel, to summarize highlights of their respective panels, and to engage in discussion with other moderators and you. I hope we can leave this Conference with ideas about additional approaches to meeting needs and accelerating action. I hope we can make results of this Conference live vigorously in the future. I hope we can prompt action programs based on better mutual understanding.

<u>This is now your Conference.</u> I thank you very much.

THE PORTER DOLWIG LAW --FOUR YEARS OLD*

By
R. C. Price, Deputy Director Policy
Department of Water Resources
The Resources Agency
State of California

This occasion marks the fourth anniversary of a most important piece of legislation -- the Porter-Dolwig Ground Water Basin Protection Law.

It is particularly appropriate that this conference be the forum to mark this anniversary; not only since it was four years ago this month that work was initiated under authority of the newly enacted law, but also that this legislation, which has proven so significant to water resources planning and development, is an outstanding accomplishment characterizing the theme of this conference.

This should be expected, for Assemblyman Carley Porter, who has always been one of the mainstays of this biennial conference and its objectives, has also been one of the legislative champions of the cause for ground water basin protection, management, and use. He works continually to improve the value of our ground water basins and their relationship to overall water resources development.

More than half of the water used in California today is pumped from our ground water basins. California's ground water use amounts to about 40 percent of the total use of ground water in the United States. Ground water played a major role in the development of the economy which supports 18 million people today. Many areas of our State enjoy an economy possible solely through use of the ground water the early settlers found beneath their feet.

I need not dwell on the past and present value of our ground water basins. I would like, however, to describe for you a new role which we envision for our ground water basins. In the past, emphasis was on the use of <u>ground water</u> in storage -- in the future it will be the use of the ground water itself <u>and the storage capacity</u> of the basins.

Adequate storage capacity is a primary concern in our water development program. It is important that this storage capacity be not only sufficiently large, but that it be available close to the place of use.

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* Presented at the Biennial Conference on Ground Water Recharge, Development and Management, Royce Hall, U.C.L.A., September 1, 1965.

Early in the studies concerning the California Water Plan, it became apparent that the necessary control and regulation of large volumes of water over long climatic cycles could not be accomplished by surface storage alone, within foreseen economic limits.

Adequate surface reservoir storage capacity was found to be available in the areas of water surplus to accomplish the required regulation. However, in the areas of water deficiency, the required storage capacity could not be found in surface sites alone. As man depletes the underground water supply, he goes outside of his area to get and import water, for which he must then find adequate local storage space.

Man doesn't concentrate his water use activities in the areas of the State where canyons are readily available for reservoir construction to meet his water storage needs. For the most part, however, sufficient ground water storage capacity is available. The use of ground water basin storage capacity has therefore become a vital component in the development of our water resources to meet the full needs of the State.

We estimate that there is a capacity to store at least 950 million acre-feet of water underground in California. Most of this capacity underlies land upon which the stored water will be utilized. Location gives this type of storage an extra value.

Clearly, our ground water basins, which have taken ages to form and which are so important to our present economy and future plans for water development, are worth preserving. We must be aware, then, that this valuable natural resource is being threatened.

In most areas of the State where ground water is pumped for use, the unconsumed portion is discarded and seeps back underground. Man's use of water results inexorably in an increase in its dissolved mineral content. This discarded waste water then, although properly treated biologically and aesthetically restored to sparkling clarity, may still degrade a ground water basin by reason of the dissolved minerals carried back into the aquifers.

Excess irrigation waters returning to the ground water aquifers contain not only those dissolved minerals added while farming, but through a natural process they become even more mineralized, thereby constituting possibly the greatest single threat to the long-term quality of our ground water basins.

In our urban society, disposal of garbage has also become a serious threat to ground water quality. Enormous quantities of solid wastes are collected and buried in sanitary landfills in canyons, exhausted gravel pits, or any convenient location. These wastes, when buried, decay. Liquid and gaseous products of decomposition form, move through the surrounding soil, and eventually reach the underlying ground water bodies as another source of degradation.

In areas where ground water basins lie adjacent to the coast, the historic pattern of ground water movement was in the direction of the ocean. However, as the demand rates exceed recharge, ground water levels near the ocean draw down below sea level. The movement oceanward is reversed, and the sea intrudes landward. In some areas this movement has penetrated as much as three miles inland on fronts ten miles or more wide.

These actions -- the improper use of a basin to collect a multitude of waste materials and the overdrafting of a basin causing the intrusion of sea water -- are two of the ways our ground water basins are threatened. How can they be protected from these threats?

California's Regional Water Pollution Control Boards have set waste discharge requirements which assist in protecting the ground water -- the State Water Rights Board assists in setting pumping limitations in adjudicated basins -- but only the Porter-Dolwig Law has recognized the need for protection of all kinds; projects, as well as long-term plans for use of the basin while preserving its utility.

The law presents a formal declaration of interest on the part of the people of the State which enables the Department of Water Resources to take the necessary action to provide fully for the protection of California's ground water resources and the furthering of our water planning effort.

The law itself is very short. It states that: "It is hereby declared that the people of the State have a primary interest in the correction and prevention of irreparable damage to, or impaired use of, the ground water basins of this State caused by critical conditions of overdraft, depletion, sea water intrusion, or degraded water quality." In addition, it provides that the Department investigate and prepare plans and design criteria for projects which are "...practical, economically feasible, and urgently needed to accomplish the purposes of this chapter', and to review similar plans which have been prepared by other agencies.

Under authority provided by this law, the Department of Water Resources has engaged in studies in several areas, and we have significant progress to report on them.

Sea water intrusion threatens the entire ground water basin underlying Santa Ana Gap, a portion of Orange County between the cities of Newport Beach and Huntington Beach. Because of the area's huge water requirements, the ground water level has dropped below sea level, and saline water has moved into the basin a distance of over four miles on a front about three miles wide.

Local authorities, notably the Orange County Water District, alarmed earlier by the threat of sea water intrusion, had adopted extensive measures of ground water replenishment through artificial percolation, to halt this degradation of the basin.

In 1961, the urgency of finding a more permanent and direct solution to the sea water intrusion problem in the Santa Ana Gap was recognized as justifying our immediate attention under the Porter-Dolwig Law.

Consequently, the Department of Water Resources initiated a program of investigation leading to a design of a sea water barrier. Consideration was accorded many types of barriers in an effort to resolve the problems introduced by geologic complexities. The report of this investigation has been completed and will be published shortly. The Orange County Water District has already taken active steps to implement the recommendations which will appear in the report. A sea water intrusion barrier project is becoming a reality. The combined efforts of state and local agencies are bearing fruit.

A second area of serious sea water intrusion damage occurs in the Oxnard Plain c tering in Port Hueneme and Point Mugu in Ventura County. Salt water has penetrated inland from each of these centers a distance of about three miles. These two expanding arcs threaten to merge and form a single front about seven or eight miles wide. The agricultural economy of the overlying area faces disaster with the continued inland sweep of salt water now advancing at some 1,500 feet per year.

Several agencies, including city and county administrations, as well as local water agencies, have requested assistance in devising measures to arrest the intrusion which threatens destruction of the ground water basin in the near future. The Department of Water Resources responded under the Porter-Dolwig Law and planned a sea water barrier. During this last session, the Legislature appropriated additional funds to commence a field test of the barrier design offering the best solution to this intrusion problems. Upon completion of the test project, a final design will be ready for construction.

The Department has launched a detailed study of decomposing solid wastes and the threat which resulting gas and liquid products present to underlying ground water.

This study necessitated developing new techniques for the conduct of the field investigation. Data resulting from these techniques have provided us with measurements, heretofore unavailable, of the extent to which organic gasses and liquids can enter ground water from a dump.

Tentative conclusions of the study indicate a need for positive barriers against the passage of gasses or liquids from the dump to the underlying ground water.

Uncontrolled overdraft or improper use of ground water basins bring on many of the problems we have surveyed. The Department of Water Resources is continuing to attack these problems in order of priority and in phase with the State's water development planning activity.

It is our intention to carry out the declared policy of the people to protect our ground water basins to the fullest extent necessary, so that the optimum benefit which can be provided by this great natural resource will be realized, through the full implementation of the California Water Plan.

A primary vehicle by which this necessary protection will be accomplished -- an already proven effective piece of legislation -- is the Porter-Dolwig Ground Water Basin Protection Law.

THE APPROACH TO GROUND WATER

Presented to: Ground Water Research Conference
University of California - Los Angeles
Los Angeles, California
September 1, 1965

By: Assemblyman Carley V. Porter
Chairman, Assembly Water Committee
California State Legislature

Mr. Chairman, Ladies and Gentlemen:

It is a pleasure to join you again for another most useful and informative ground water recharge conference. I am particularly fortunate and honored in being selected to lead off the discussions today. The topic that has been assigned to me is "The Approach to Ground Water," which taken in the context of this morning's subject - the Broad Approach to Ground Water - gives me a rather wide area in which to talk, although my approach to ground water is primarily a legislative one.

First, may I say that I appreciate, and I know Senator Cobey also appreciates, the opportunity for legislative participation in these conferences over the years. The fine work in the field of ground water which has been done by local people and the State and Federal agencies in California is most important. But, in the last analysis, the Legislature inevitably is drawn into ground water matters either by enacting laws or in budgeting State activities in this area. We enjoy very much participating with you and learning from you in conferences of this type.

You will probably recall that during the interim period between the 1961 and 1963 legislative sessions, the principal subject studied by the Assembly Water Committee was ground water. We issued a report to the 1963 Session entitled "Ground Water Problems in California." At that time, we attempted a broad review of the political, legal, economic and technical aspects of ground water. Our report concluded that, "No legislation is being recommended because the approaches to ground water management currently used in the State, when properly understood and applied, appear to be adequate." We added, however, that, "If specific problems arise in the future, legislation can be drafted to handle them at that time."

Since the issuance of that report, there have been many important developments on the local level in the field of ground water. The West Basin adjudication has been finally completed, the Central Basin's stipulated judgment has been entered, and somewhat regrettably, the users along the Santa Ana River have engaged in even more lawsuits than in previous years.

During the time since our report, local areas have continued to expand ground water replenishment activities of the type pioneered by the Orange County Water District. The Legislature has also given authority to other water districts in all areas of the State to engage in replenishment programs.

I might add that at the 1965 Session, legislation sponsored by the Assembly Water Committee permitted the Water Replenishment District Act to be used to form districts throughout the State. Water replenishment districts were formerly limited to certain Southern California counties. I hope that as a result of the 1965 legislation, this excellent act will be used as a means of bringing replenishment programs to areas that need them as the bill recognizes the statewide need for ground water programs.

At the 1965 Session, I also introduced legislation (AB 2707) recommended by the Department of Water Resources which, in its original form, would have provided for State water well standards to protect our underground waters. The bill also transferred the responsibility for water well reports to the Department of Water Resources from the Regional Water Pollution Control Boards. A great deal of concern over the bill was registered by many local people and as a result, as the bill was finally adopted, it did not include State standards, but did transfer the responsibilities for water wells to the Department and also added a requirement that a notice of intent to construct or modify a well be filed with the Department prior to commencing work on a well. The latter is a new concept.

The discussions on ground water which were held during the session, the work that the Department has put into Bulletin 74, "Recommended Water Well Sealing Standards," as well as the fact that we have had several years now of additional ground water experience since our last report, has convinced me that the Assembly Water Committee must again return to the field and actively work in the area of ground water.

The Speaker of the Assembly and the Rules Committee have approved my request to establish a special Ground Water Subcommittee of the Assembly Water Committee. I am pleased to announce the Subcommittee has been appointed and our first hearing will be held in Sacramento on September 23. At that time, we will begin discussions of ground water problems in California starting with the matter of water well standards and including consideration of cost sharing of ground water basin studies between the State and local agencies. The entire subject of the need for conjunctive use of surface and ground water supplies in California will also be before the Subcommittee.

At the 1961 Session of the Legislature you will recall that the "Porter-Dolwig Ground Water Protection Law" was enacted and at the last two of these conferences we discussed some of the activities undertaken as a result of this act. I would like to just take a minute to briefly indicate the extent to which California's ground water studies have accelerated under the policy declarations of this act and through appropriations by the Legislature to the State Department of Water Resources.

Since 1961, we have added or expanded the following ground water programs under the policy declaration of the Porter-Dolwig Act:

San Joaquin County Ground Water Investigation

Orange County Coastal Plain Investigation

Sea Water Intrusion Studies

Planned Utilization of Ground Water Basins

Mojave River Ground Water Investigation

A complete list of all of the State studies undertaken pursuant to appropriations under the Porter-Dolwig Act is attached to the prepared copy of this speech.

I might add that in addition to Porter-Dolwig studies, at the 1965 Session of the Legislature $310,000 was appropriated to the Department of Water Resources for the 1965-66 fiscal year to begin an experimental study of a sea water intrusion barrier for Ventura County utilizing the revolutionary trough method of hydraulic barriers. This action resulted from a program prepared by Assemblyman Burt Henson on behalf of the water leaders of Ventura County.

It is significant that the Legislature has again recognized the statewide interest in combatting sea water intrusion as it did in 1951 when it assisted Los Angeles County in the first test barrier along Manhattan Beach. Today the State is helping to develop an important new and unique concept in ground water protection from sea water intrusion in the trough barrier.

In approaching our ground water studies this year and in reviewing the Committee's past work and ground water developments of the last few years, I have become increasingly aware of the fact that maximum conjunctive use of surface and ground water supplies in California is an absolute necessity. It seems to me that new legal machinery and new concepts of ground water management must be evolved if such conjunctive use is to be truly successful.

You will recall that in the early 1940's water began to flow through the recently completed Metropolitan Water District Colorado River Aqueduct, but for the first decade of service it carried only a small part of its designed capacity while ground water pumping in the south coastal basin continued to accelerate. The future water need was then hard to predict, the local organizational structures for raising funds to replenish underground basins were not in being -- in short, a water crisis was then not at hand.

Only in the 1950's did the Metropolitan Water District Aqueduct begin to operate at half capacity when a ground water replenishment program got underway, and only in the last few years has the Aqueduct provided the full Colorado River entitlement to the coastal plain. Now the Metropolitan Water District estimates that water demand

in its service area will exceed the supply during the three years immediately preceding arrival of Feather River Project water in Southern California, and that ground water basins will be relied on to meet this need.

Although Metropolitan Aqueduct is operating at maximum capacity, the Supreme Court decision in Arizona v. California has been concluded and California now finds itself facing a certain cutback in our Colorado River supply. We have a ground water reserve to call upon before additional imported supplies are available, but we did not take full advantage of storing up our water supplies during the time the Metropolitan Aqueduct was partially unused and we did not save for that "winter" which has come upon us.

But this is past history and the Southern California water agencies have contracted for more than 2 million acre feet a year from the Feather River Project. This area also vigorously supported the $1.75 billion bond issue to make this possible and I am sure will support local bond issues for construction of distribution systems which in Southern California alone will cost nearly $1 billion.

Southern California now faces a challenge even greater than that of the past decades. In less than six years the Feather River Project will be delivering surplus Northern California water to Southern California. Deliveries in the first years will be just a part of the total water which will eventually be provided by the Project. During the first few years the California Aqueduct is planned to run at only partial capacity.

A tremendous opportunity is available for Southern California during the next few decades to store water from the Feather River Project in underground basins in Southern California. The experts have studied the geology and hydrology of Southern California and have stated without exception that there is not enough potential surface terminal storage in Southern California to make a maximum use of State Project water.

The time has come for all of us in the water field to work together developing new methods and procedures with which we can make maximum use of Feather River Project water in Southern California. It is time for all Southern California people -- at either end of the rivers, from all parts of each basin, water users of all types -- to set aside differences and recognize once and for all that old truth which has been repeated endlessly -- "lawsuits do not produce new water."

Every day we are engaged in a lawsuit instead of working together developing water, water is being lost forever. The great English poet, John Donne, on a loftier plane, wrote, "No man is an island, entire of himself. Every man is a piece of the continent, a part of the main."

Today, particularly in Southern California, but throughout the State, there is no doubt in my mind that no single district, no single group, no single area, can afford to be an "island," and "go it alone" in this effort. We are all part of a great State.

As the Water Committee undertakes its studies this year, we are going to be anxiously awaiting the development of constructive and logical means of assuring the maximum use of the underground basins of Southern California, particularly with regard to the possibilities of utilizing tremendous quantities of Feather River Project water in the early years to make certain that the future of Southern California is assured through ground water storage.

The problems of guaranteeing that water will be available when the Feather River Project reaches its full capacity, and when Federal projects adequately resupply the Colorado River, is, of course, important. But, we can be doubly assured of that future if we have within our grasp a plan for conjunctive use of our surface supplies and ground water basins.

This, I think, is the challenge that is facing us in the ground water field today. It is true that we need additional geologic information and, in fact, we need technical data of all kinds. But, State, Federal and local agencies today are doing more than ever before to get that data and I am sure this emphasis will continue.

I believe that there is no doubt that the political and legal apparatus available now to meet this challenge is at best a little creaky. We in the Legislature, however, stand ready to accept the challenge of finding a way of solving this most pressing problem and providing whatever new laws are necessary.

We hope you will accept this challenge and join with us in assuring the future of ground water basin management in Southern California and more than that, the future water supply of a major portion of our State.

# # #

Department of Water Resources

"Ground Water Basin Protection Studies"

Porter-Dolwig Ground Water Basin Protection Act

Salinity Barrier Studies, Santa Ana Gap, Orange County

San Diegito Basin Study

Santa Clara River Salt Balance Study

Oxnard Plain Salinity Barrier Study

Sanitary Landfill Study

San Jacinto Basin Salt Balance Study

Bolsa-Sunset Gap Salinity Barrier Study

South Bay Ground Water Investigation

Livermore Valley Ground Water Basin Investigation

COMPREHENSIVE PLANNING

by

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Introduction

I want to take this opportunity to pay a personal tribute to the Honorable Carley V. Porter, member of the California Assembly from Compton and to Senator James Cobey of Merced County. It has been my great privilege to have worked closely with Assemblyman Porter for more than 10 years. It is to their leadership and hard work that the State of California owes its present leading position in all aspects of water development, not the least of which is ground water. The fame of these two legislators extends far beyond California.

This discussion will consider ground water and planning for development of groundwater resources only as one aspect of the total task of comprehensive water resource planning.

Several of the illustrative examples used have been drawn from Texas. The State of Texas through the Texas Water Development Board is now engaged in one of the most ambitious and comprehensive planning efforts ever undertaken by any governmental jurisdiction. Texas is developing not only a long range Texas Water Plan which will go far beyond the California Water Plan in scope, but also a Texas Water Program for the next quarter century. This program may not require quite as great a financial outlay on the part of the State as the current $2.5 billion California program but will include a greater scope of activities. I have the honor to be one of the consultants to the Texas Water Development Board in this effort.

Present Planning Concepts

We can no longer afford the concepts or the types of planning for water resource development that are now current. All too often the result is not only wasteful of water resources, money and

materials, but also in some cases, other natural resources are destroyed which would have been equally or perhaps more valuable than the water that is purported to be made available for beneficial use.

The usual types of planning can be classed in four different categories. First is simply an overall physical scheme which indicates what structures could be built to conserve and transport specified amounts of water from particular sources for beneficial use in certain areas and purposes. Generally, such physical schemes have given little consideration to the probable economic need for the water and for the other products of the proposed development(s). The need is assumed to exist, an assumption which may or may not be supportable.

Then there is the inventory type of planning; that is, an inventory of available water resources is made, an inventory made of water requirements, and a physical scheme formulated to relate the development of resources to requirements. In this type of planning, too, little consideration has been given in most cases to the economics of water supply in estimating requirements.

Both of these types of planning efforts often lead to over-investment.

The third category is what is termed the "comprehensive river basin plan," generally done by a specific agency under its particular authorizations and policies, and in most cases, with the basic objective of obtaining authorization for a construction program for that particular agency. Such a plan, for example, is the comprehensive plan for the Trinity River and Tributaries in Texas recently completed by the Corps of Engineers and now before Congress for authorization. Basically, this is a plan to provide for navigation from the Gulf of Mexico inland as far as Fort Worth and for flood control on the Trinity River and its tributaries. Some attention has been given to other functions such as water supply and recreation but only on an intra-basin basis. The interrelationship of the Trinity River Basin with other areas in Texas in water matters was not considered. The plan is not "comprehensive" in the true sense of the word.

This is not meant to be critical of the Corps. It was done in response to a directive from Congress. Nonetheless, the result is one which largely ignores regional inter-relationships and needs, particularly the necessity to transport surplus water from the basins to the east of the Trinity River basin across that basin, either directly or by exchange, to areas of deficiency lying to the west. The plan as now formulated could have a distinctly adverse effect upon the fish and wildlife resources of Galveston Bay and the Gulf of Mexico, and upon the recreational and other uses of these latter waters.

A fourth type of planning which is often mistakenly labeled "comprehensive," is essentially a project feasibility study. The Texas Basins Project report proposed by the Bureau of Reclamation is such a plan. It is thought of as a comprehensive plan, primarily because it touches a number of river basins. This $1.2 billion Reclamation project would transport surplus water from southeast Texas for irrigation in the Lower Rio Grande Valley just north of the Mexican border, by means of pumping plants and a canal slightly over 400 miles in length running roughly parallel to the Gulf coast about 40 to 50 miles inland. Water would also be furnished to the cities and industries along the Gulf coast. There is little question as to the immediate benefit to the entities served directly, but the project would have a profound impact, adverse in some degree, on the economy of the remainder of Texas, a matter that was not considered in the planning. As the project was originally formulated by the Bureau of Reclamation, it would have resulted in the destruction of most of the fishery resources in the bays and estuaries along the Gulf coast.

In these types of planning, the economics of resource allocation are almost completely ignored. In fact, some of the laws and policies undr which planning is done, particularly at the federal level, prevent proper resource allocation. The basic fault lies with Congress which has never seen fit to enact a consistent national water policy but rather has set up a number of competing and conflicting programs.

Alternatives such as increase in efficiency of use, nuclear power generation as an alternative to hydroelectric power, desalination, and reclamation and reuse of waste waters, are properly and fully evaluated only infrequently. The costs involved in alternatives may

be substantially less than development of new fresh water sources. For example, the cost of reclamation of waste waters for reuse in Southern California is low as compared to the cost of additional imports from Northern California. The regional economic impact and consequences of the larger projects, particularly those designed to meet a specific problem in a particular area, are not taken into consideration adequately. Ecological effects are seldom considered. This has been particularly true of the Gulf Coast of Texas. Until this year, all of the planning for water development in Texas has been based upon the assumption that fresh water inflows to the bays and estuaries bordering the Gulf of Mexico could be completely cut off if the water appeared to be utilizable for other purposes elsewhere. The facts of life are, however, that if some fresh water inflows to these bays and estuaries are not maintained, the sport and commercial fishery resources will be largely destroyed and the recreational use severely affected. The impact would extend to the waters of the Gulf of Mexico proper. The ecological consequences have been ignored.

Only recently, within the past four years, have we begun to give any serious thought to effects on fish and wildlife resources, and only in the past two or three years has quality been considered worthy of much attention. Except in California, and more particularly in Southern California, so-called comprehensive planning has almost completely neglected ground water resources and underground storage capacity. We have been preoccupied with dams and reservoirs, power plants and canals.

One final aspect of the weaknesses in comprehensive planning under present concepts is that, except in Southern California and to a lesser extent elsewhere in California, no thought has been given to the integrated management of the several water resources available to a given area. To illustrate, one of the reasons that there is a severe water shortage in certain portions of New Jersey at the present time is that there is no mechanism for integrated management of that State's water resources in toto. There are reservoirs in New Jersey which still have a considerable amount in storage, but they belong to specific water purveyors and there is no way that other water service agencies which are not so fortunate, can draw on these reservoirs.

In New Jersey, too, the relatively large ground water resources available have been largely neglected although some industrial plants have drilled their own wells. There has been no coordinated development and management of the ground water resources.

Guidelines for Planning

What are some of the concepts that should guide planning if it is to be truly comprehensive?

In the first place, it must be realized that planning is only one step in the total process of controlling, protecting, conserving, distributing and utilizing water resources. It is not an end in itself. Planning, to be effective, must encompass much more than simple inventories of resources and potential requirements, and the development of possible systems of physical works to meet those requirements from the available resources. In the planning process, consideration must be given to the agency or agencies which are expected to implement the plan through the construction and operation of facilities, and to those which will participate in the financing and repayment.

Each of the agencies at the various governmental levels has specific powers, objectives, functions, policies and philosophies, pursuant to the laws under which each operates. The laws and policies under which some federal agencies operate automatically impose an economic bias with respect to specific uses of water; for example, the non-reimbursability of costs allocated to navigation and the subsidies to irrigation under the Reclamation program. These have a major effect on the allocation of water resources to the uses concerned.

Provisions for the integrated and coordinated development and management of the water resources, by or through existing agencies, or by creation of some new agency, should be fundamental to a comprehensive plan.

With certain exceptions, such as water for direct human use, water development is necessary only as an adjunct to the development and utilization of other resources to meet human needs.

Therefore, investigation and planning with respect to these other resources should precede and form the base for water resources planning. Population projections, for instance, should take into account the availability of land and other natural resources to support the future population in accordance with desirable economic and social objectives under proper land use and with due regard to such matters as transportation and, most important, the proper disposition of wastes. Planning for irrigation should consider the probable need for an increase in the crops to be grown, both locally and on a national scale, and for export, and the significance of irrigation to local and state, as well as the federal economies. Alternative locations for expansion of irrigation need to be evaluated.

All feasible alternatives should be fully evaluated, including such things as reclamation and reuse of waste water, desalination, and the reallocation of resources among uses as new uses develop.

Social, as well as economic goals and objectives must be clearly defined; this is rarely done. All economic, social and ecological effects, both beneficial and detrimental, should be evaluated and means provided to mitigate detrimental effects to the maximum feasible extent. Contrary to the opinions of some economists, efficiency of investment is not the sole criterion to be considered.

Planning should encompass the conjunctive use of surface and ground water resources, and of surface and underground storage where these are physically or economically interrelated.

Planning should be on a regional basis, not necessarily on a river basin basis alone. The needs and the problems of the entire region, including the areas of origin which are or may be dependent upon the water resources involved or affected by the development of those resources, should be considered and incorporated in the comprehensive plan; "protection" for the basins of origin is not enough.

The proper areal or regional scope of comprehensive planning cannot be determined in advance in all cases. This has been recognized in the proposed legislation for regional planning for the Colorado River Basin and the augmentation of supply thereto; here the total region that may be finally encompassed within the plan cannot be specified now.

The popular concept of "river basin" planning inherently indicates some confusion as to the fundamental purpose of planning, that is, is it for the development of water resources as an objective in itself, or is the objective of planning to serve human needs where and when they arise. It is indeed unfortunate that Congress saw fit to perpetuate this unrealistic concept of the river basin as the proper basis for planning in the Water Resources Planning Act of 1965.

Finally, planning must be conducted as a multidisciplinary process involving not only engineers and geologists but also resource economists, biologists, lawyers, geographers, and many others. Too long have we regarded this as a task that any so-called planner can accomplish.

Conclusion

To accomplish all of this, we need a new organizational structure for planning. Perhaps the river basin commissions authorized under the Water Resources Planning Act of 1965, can be developed into competent planning organizations. Extensive amendments to the Act will be necessary but at least it is a first step in that direction. More importantly, new concepts of planning, some new ideas of what should be considered and evaluated in the planning process, and improved methologies must be developed before we will have truly comprehensive planning. Perhaps the greatest need of all is to develop the institutional arrangements and organizational structure for integrated management of water resources.

GROUND WATER RESOURCES PLANNING*

By
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While ground water use has developed in California for more than a century, it was not until relatively recent years that our ground water resource has commanded widespread attention. This is not difficult to explain.

From the earliest rudimentary developments, methods of "tapping" underground water supplies have advanced in sophistication and efficiency -- from dug wells with bucket and windlass to windmills, to centrifugal pumps, which were good for shallow draft, to the advent of the deep well turbine pump and the efficient electric motor. During the earlier development period, demands on ground water basins were but slight in relation to replenishment or to the water in storage, deposited over the ages. The vast underground reservoirs were considered to be virtually inexhaustible.

The ready availability of ground water favored its development and use by individuals, and later on by local districts, with a resultant uncoordinated exploitation with little or no concern for the relationship between withdrawals and replenishment. However, this availability, coupled with the evolution of more efficient techniques of extraction and the tremendous boom in California's economy since the 1930's, has resulted in a phenomenal increase in pumping. The results have brought us abruptly to the stark realization that our ground water resources are not inexhaustible -- that draft cannot indefinitely exceed replenishment rates if we are, indeed, to enjoy the continued use of those resources.

I need no more than cite the serious problem of overdraft and the consequent sea-water intrusion into our coastal aquifers, the declining water levels in our interior basins, such as the San Joaquin Valley, the intrusion of connates or other water of undesirable quality into pumped aquifers, and increased mineral content of ground water in general.

Although our ground water basins are overdrawn, they are being pumped ever more heavily. Concurrently, the natural sources of replenishment to those basins are being reduced through the encroachment on recharge areas by pavements and roofs, and the sources of recharge are being diminished by the construction of storage and diversion facilities to develop the water for surface application.

*Presented before the Biennial Conference on Ground Water, Recharge, Development, and Management at the University of California, Los Angeles, September 1, 1965.

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In spite of these overdraft conditions, the ground water basins are now, and will remain in the future, of vital importance to the future well-being of the State. We must not only rely upon maintenance of their present utility, but we must also plan for steadily increasing use of storage underground to complement both locally developed and imported surface water supplies as they are extended to meet rapidly increasing growth throughout the State.

Is this an anomaly? Certainly it is not -- providing we understand the nature and occurrence of ground water, and of the factors pertaining to the replenishment and use of underground storage capacity. Ground water basins may be considered the counterpart of surface storage reservoirs. Their operation involves the same general principles -- to equate on a time basis differences between water supply and demand.

Our major surface reservoirs are designed with sufficient carryover, or cyclic, storage to provide water delivery over the extended drought periods which are characteristic of California's climate. These reservoirs then fill during ensuing wet periods. Ground water basins are no different. They are drawn down during dry periods of scanty replenishment, and are filled during ensuing wet years when runoff and rainfall are abundant.

It is important that a distinction be drawn between ground water in storage and ground water storage capacity. Ground water in storage is important; however, it is of a transitory nature, and is subject to depletion, or exhaustion, if not replaced. Perhaps of greater importance as a natural resource is ground water storage <u>capacity</u>, with its recharge and withdrawal capabilities. Storage capacity can be used with equal effectiveness, regardless of the source of replenishment.

The California Water Plan contemplates three general categories of use of ground water basins in conjunction with surface water storage facilities to meet California's future water requirements. These categories are also distinguished by their geographical locations. The first category consists of the coastal and southern areas, which will depend heavily on imported water supplies. The principal functions of the ground water basins in these areas are to provide terminal regulation for imported supplies, in addition to the conservation of local supplies.

The second category involves the San Joaquin Valley, where underground storage will play a major role in the conservation of local supplies and will also be employed to regulate excess waters imported from the north in wet years.

The third category includes the Sacramento Valley where total water supplies generally exceed local requirements. The basin capacity, coupled with surface developments, not only can supply local demands, but can provide regulation for water to be exported.

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Current studies of the Department of Water Resources are premised upon those three categories of ground water use. We do not in any manner contemplate state operation of ground water basins, but we do believe the indicated categories of use are necessary to the balanced and most efficient overall development of California's water resources to meet future needs. We are hopeful that our studies will show the way to the operation and management of ground water basins, thus providing a framework, or guide, for implementation by local agencies.

Here in the South Coastal area, it is estimated that annual water requirements will increase some 3 million acre-feet by 1990 and some 5 million acre-feet by 2020. Much of these additional water needs will be met by importation from Northern California, through facilities of the State Water Resources Development System. Water may also be imported through facilities of a regional water plan. But, irrespective of the source of imported water, economics will dictate its delivery on a continuous flow basis. Terminal storage will be required to regulate the uniform deliveries to monthly demands in the areas to be served. The scarcity and high cost of surface reservoirs to provide this regulation will dictate the increased and substantial use of underground storage at an early date to augment surface reservoirs. This is an existing practice in regard to regulation of water imported from the Owens and Colorado Rivers.

Studies by the Department indicate that more than one million acre-feet of additional storage capacity will be needed in Southern California within the next 50 years to provide emergency storage and terminal regulation of imported northern water supplies. Fortunately, there are large volumes of storage space available in known ground water basins in the vicinity of the best aqueduct routes, and, in some instances, underlying the places of use. If it is feasible to use these underground storage sites, considerable savings in capital outlay may be effected, as compared to the cost of accomplishing such regulation by surface storage alone. Moreover, the underground storage reservoirs will continue to function as important natural distribution facilities, and are not subject to the evaporation losses characteristic of surface reservoirs.

The San Joaquin Valley offers a tremendous opportunity for future broad-scale planned utilization of ground water storage in conjunction with imported water. It would require an annual supplemental supply of nearly 2 million acre-feet to offset the present ground water overdraft. It is forecast that the import requirement will increase to 4.5 million acre-feet by 1990 and to nearly 7 million acre-feet by 2020. Most of this increase, as well as the present overdraft, will be met by importation of water from Northern California under planned federal and state projects.

Initial future deliveries to the valley will be made through the joint state-federal San Luis Project. The facilities will deliver water to the service area on a uniform annual basis,

with cyclic carryover storage being provided by surface reservoirs. As the demand increases later in the future, the use of a substantial amount of underground storage in the San Joaquin Valley will be required to supplement available surface storage in providing final regulation to a relatively uniform annual demand. Furthermore, the transfer of the variable surplus water supplies from the north will necessitate the construction of increased capacity in future conveyance facilities.

As Northern California surface storage facilities become more costly, the ground-water basin underlying the Sacramento Valley may, on the basis of cost, be an attractive source of water for export. Much of this underground storage is now unused, as water levels are not drawn down to provide space for recharge during wetter years. Certainly, the combined use of ground water and surface water storage capacities could provide water for export in excess of that which can be developed by surface storage alone. Future operations in the Sacramento Valley may provide withdrawals from underground storage in dry periods to augment water supplies in the Delta.

As I indicated earlier, the State does not contemplate ground-water basin management. The State's role is to develop and transport water to major areas of use, within ground water basin operational concepts; but it will be the responsibility of local districts to implement ground-water basin management.

Now, let us consider planning for ground-water basin management from the local agency standpoint.

First, the physical facts must be determined. This is the investigative phase which determines the basic information necessary to the development of a management plan. The more significant information required is storage capacity, transmissibility, permissible withdrawal and recharge rates, water quality, present demand on the ground-water basin, safe yield of the basin under both present and future levels and patterns of extraction, and the overdraft.

Secondly, the physical facts must be tempered with practical economics to formulate a management plan. In this regard, the Department is currently engaged in a program of study of the planned utilization of ground-water basins in Southern California and in the San Francisco Bay area. In Southern California this study program was initiated in the Los Angeles County coastal plain in 1959. As the study of each basin is completed, a report will be published providing information on a range of possible plans for consideration for implementation at the local governmental level. Each of the plans will encompass the economic utilization of underlying ground-water storage capacity in conjunction with local and imported surface-water supplies to meet future water requirements.

Finally, an agency must be established with sufficient powers to undertake broad-scale ground-water basin management. Several requisites are necessary to this purpose. First, its political boundaries must encompass at least the entire area of the underlying ground-water basin. Secondly, the agency must have the authority to purchase, contract for, or otherwise finance the delivery of a supplemental supply. Lastly, the agency must have legal authority to regulate and integrate the local and imported surface-water supplies with ground water into the planned pattern of overall water use. There are a number of agencies that have some of these powers, but there exists no district today that has all of these powers.

In this regard, I wish to emphasize that we cannot have complete ground-water basin management unless the plan provides for the full satisfaction of the economic water demands. We must not confuse regulation alone with ground-water management. While the restriction of pumpage may protect a ground-water basin, it does not make full use of the ground-water resource.

The matter of granting appropriate powers to a local agency to integrate all sources of water into a planned pattern of overall water use raises serious questions concerning the adequacy of current concepts of water rights. Our existing water-right concepts attach a <u>property right</u> to the use of water from a particular source. However, the management of total water resources to meet all economic demands cannot be efficiently accomplished under such a system.

To be fully effective, in my judgment, management should provide a right to a water <u>supply</u>, irrespective of source. This would enable the integration of both surface and underground storage facilities to provide the most economical overall water service, which includes both development and transmission.

Such an integrated management program would involve total water resources pooling, both local and imported, and stored in both surface and underground reservoirs. Under the pooling concept, each user would be entitled to a specific supply of water, but the source might be ground water, a local surface storage facility, an imported water supply, or a combination of all. Water costs could be computed on the basis of overall supply, such costs equitably allocated to the users. Users having capital investment in wells and other facilities could be recompensed by an appropriate adjustment in the price of their water supply. Under the pooling concept, water charges could be made by a combination of pump tax, ad valorem tax, and direct charge for surface waters.

I recognize that a pooling concept of operation, which would supersede the present concept of ground-water rights, would pose special problems. The possible change in pumping patterns

to maximize the use of ground-water storage may well change the water source for many users. The development of a practical method of computing and assessing equitable charges to the water users will require careful study.

However, this general concept really is not new. Consumers in metropolitan areas take their water from a common system. They are guaranteed a supply, but have no control regarding the source of the water.

In closing, I might observe that I have been idealizing to a considerable extent -- that I have been talking in terms of results rather than of the long and painstaking efforts of all levels of government that surely will be required before full-fledged total water resource management can be achieved.

The Department of Water Resources will continue its studies to identify and assist in solving physical and engineering problems associated with the management of our underground basins, and will develop recommendations with regard to changes in institutional considerations that will be required to enable the implementation of sound ground-water basin management programs.

It will be the role of the Legislature to clear the way for the establishment of appropriate districts endowed with adequate powers to undertake full-scale water resources management.

Finally, it will be the responsibility of each of us to embark on an education program designed to create the appropriate political atmosphere for acceptance of the broader concept of the use of ground-water basins in broad-scale water resources management.

We in California have made considerable progress toward ground-water-basin management; but we still have a long way to go. It is encouraging to note the large forward stride that has been taken since the time of the first Biennial Ground-Water Recharge Conference in 1957, particularly in the change in attitude toward this important subject. I do not wish to minimize the serious physical, economic, legal, and political problem still to be solved. However, general understanding and acceptance of the concept is the first, and perhaps the most important, step toward this necessary and important goal. It is in this area that we, the participants in the Recharge Conference, can make a most valuable contribution.

TECHNICAL APPROACHES

TO

PLANNING FOR GROUND WATER

Biennial Conference on Ground Water
University of California
at Los Angeles
September 1, 1965
Carl Fossette

TECHNICAL APPROACHES
TO
PLANNING FOR GROUND WATER

On the evening of January 14, 1947, a group of leading citizens were sitting in an empty real estate office, on Manchester Boulevard, in the City of Inglewood. They were the first planners for ground water in the West Basin. They had planned a municipal water district so they could get imported water to supplement their failing wells. An election had been held that day, and they were ready to celebrate. But, as the returns came in, it was clear they had lost by an overwhelming negative vote. There was no celebration.

But they did learn one lesson that night----"An effective plan for ground water requires political approval", they also learned a practical approach, "If you can't beat them----don't join them----leave them out!"

Political approval of a basin plan means higher taxes and increased water charges. For this reason, approval is usually denied, unless the need is great. Inland cities in West Basin felt safe from sea water intrusion. They voted down the proposal to join the Metropolitan Water District. So, the first political approach in West Basin was a failure.

Since then the planners have slowly learned that other principles also apply to ground water. Here are some of them:

1. Planning for ground water can best be accomplished locally, by the people directly concerned.

2. Planning should be flexible to meet changing conditions.

3. When replenishment and pumping are controlled, whether wisely or not, ground water is being planned.

4. Where necessary, planning should concern itself with pumping patterns and water quality.

5. The rate charged for imported water is a controlling factor in the type of plan that should be adopted.

6. Where the ability to replenish is limited, the highest use for ground water is to supplement surface deliveries during times of greatest need.

7. Where several basins comprise a stream system, planning must be effective among basins, as well as within basins.

The solution of basin problems would be easier if all areas suffered water shortage at the same time, but they don't. Communities farthest from the source of supply are the first to be hurt, and they are the first to seek a solution. Those closest to the source still have water, so they oppose a solution because of the cost.

Sometimes, a piecemeal solution is the only answer. For example, three interconnected basins comprise the San Gabriel River system. Water shortage first occurred in the West Basin, the one farthest from the source. West Basin Municipal Water District was formed at a second election held in November, 1947, and it joined Metropolitan in 1948. The inland cities were left out, but they joined later at their own request.

As the shortage moved upstream in later years, Central Basin formed a district in 1952 and it joined Metropolitan in 1954.

The shortage continued to move upstream, to the very source of supply, and the Upper San Gabriel Valley formed a district in 1960. It joined Metropolitan 2 years ago in 1963. Four cities in the Upper area chose a different course. As an alternative, they formed a separate district and signed a contract for State Project water. One city, West Covina, did nothing at the time, but it will vote on joining Metropolitan this fall.

A political solution for the San Gabriel system has required 18 years and 13 elections, including one failure, to obtain the imported supply essential for controlled replenishment. One more election must still be held in West Covina.

It was soon apparent that a legal approach was also essential. Despite the availability of imported water, no producer would voluntarily curtail his pumping, unless all others did likewise. An action for adjudication of water rights in West Basin was filed in 1945. This fixed the relative rights of all parties as of the date of filing, (additional parties were brought into the action later and rights were finally fixed as of 1949). The action was settled by stipulation 17 years later, but pumping was curtailed by voluntary agreement in 1955. Since then Metropolitan has furnished 70% of the water used in West Basin and only 30% has been supplied from ground water.

A legal approach was needed to secure zone amendments to the Los Angeles County Flood Control District Act. This was accomplished in 1951 to finance construction of the fresh water barrier on the West Coast and the Alamitos barrier in Central Basin. The zones also financed the purchase of the first replenishment water in 1954 through the levy of a property tax, not exceeding 5¢.

An attorney's committee, representing producers, prepared, introduced and secured adoption of the Water Replenishment District Act in 1955 (Division 18, California Water Code). The Act authorized formation of a local agency to assume basin management responsibility under the direction of local people. A replenishment district, comprising Central and West Basins, was formed at a special election in 1959, after 1500 volunteers had obtained 150,000 signatures on the formation petition.

Meanwhile, the Upper San Gabriel Valley area above Whittier Narrows was making slow progress toward obtaining an imported supply. The natural replenishment from that area to Central Basin was being diminished because of upstream interception. Again a legal approach was indicated and an action was filed in May, 1959, by Long Beach, Compton, and Central Basin, to determine the rights of major upstream users and to prevent them from exceeding such rights.

The action has now been settled by stipulation. Judgment will be entered this fall and its terms will be administered by a court-appointed three-man watermaster, to be nominated by the parties. The judgment will settle the problem of inter-basin supply along the stream system and it will make planning effective among the basins of that system, as well as within them.

In January, 1962, the Replenishment District brought an action for adjudication of water rights in Central Basin. This was done at the request of Central Basin producers. Although imported water had been available for 8 years, almost none of it was being used. Producers in Central Basin would not individually curtail pumping and risk impairment of their water rights. It was not possible to spread enough Colorado River water to prevent lowering of water levels, so controlled pumping was necessary.

In the short span of 9 months from the filing date, 80% of Basin production was under voluntary curtailment by agreement of the parties. Judgment will be entered this fall by stipulation of more than 1,000 parties to the action. Forty percent of the water used in Central Basin is now imported. Less than 15% was imported before the action was filed.

Since most of the Upper San Gabriel Valley has an imported supply, a replenishment program is possible. A start in the spreading of Colorado River water was made there last year and will be expanded this year. Water levels in the Upper area are the lowest of record and are still receding.

The enactment this year of Assembly Bill 1685 will give replenishment powers to the municipal water district in the Upper area and large scale replenishment will be possible, commencing in July, 1966. The cost of Colorado River water for spreading will then be shifted to a pump tax, thus relieving the ad valorem tax payer.

The use of political and legal technics has settled the problem of water rights, has provided an imported water supply, and has controlled pumping where necessary. This clears the way for an administrative approach to ground water planning.

The Central and West Basin Water Replenishment District conducts an engineering survey of its area each year to determine ground water conditions and the amount of replenishment water needed. The survey report is mailed to producers and a hearing thereon is held.

A replenishment assessment is then levied to be collected quarterly on each acre foot of water produced in the ensuing year. The money so collected can only be used to buy water. Operating expenses are paid by a tax levy on property. The rate has never exceeded one-half cent and is one-quarter of a cent this year.

The District mails monthly production forms to all operators of wells in its area. The form lists all wells by number and includes the last meter reading for each well. The operator records the present meter reading, he signs the form and returns it, in a postage paid envelope.

The production so reported is computed by data processing and a machine printed summary is mailed to the operator for his file. If an error occurs, he informs the District. Each quarter a machine printed statement of the assessment due is mailed to the operator for his signature and return with payment. Ninety-five percent of production is metered; the remaining 5% is estimated by the operator using a water duty table, developed by the District.

Through machine processing, the District furnishes production figures for the water year, fiscal year, calendar year and by months to the Watermaster, the Flood Control District, and the Metropolitan Water District. The producer does not have to make the special reports that would otherwise be required for those agencies.

Support for the program is beyond anything anticipated. In 5 years the District has assessed and collected 8.9 millions of dollars for replenishment water. In 5 years uncollectible "bad debts" have totaled $202.53.

Local management by local people now controls replenishment and pumping in the lower area, and may soon do so in most of the Upper area. Water quality problems and the arrangement of more desirable pumping patterns, remain as continuing problems of management in all areas.

When completed this year, the barriers will ultimately recover portions of the coastal basins intruded by sea water. Increased extractions under emergency conditions will then be possible without endangering the basin supply.

The disposal of refuse in some areas overlying the ground water supply would, if permitted, threaten ground water quality. All such proposals are being actively opposed.

The Replenishment District is expected to take the first step toward arranging pumping patterns in its area this year. If approved by the Board of Directors, a contract may be offered to certain producers providing for payments to be made following a yearly reduction in pumping and the use of imported water in lieu thereof. The resulting further reduction of pumping in areas adjacent to the barriers will be a helpful rearrangement of the pumping pattern.

Important questions remain for the future. Here are some of them:

(1) Should changes in pumping patterns be mandatory?

(2) To what extent should reclaimed water be used?

(3) Should it be used for the barriers?

(4) Would it lose its identity if injected?

(5) At what elevation should water levels be maintained?

Answers to these and other questions will be found as needed.

No single agency is responsible for progress in the basins of the San Gabriel River system. For example, the Flood Control District operates the barriers with water purchased from Metropolitan through Central Basin Municipal Water District and paid for by the Water Replenishment District with funds from a pumping assessment.

The Whittier Narrows Reclamation Plant was constructed by the Sanitation Districts with money loaned by the Board of Supervisors, to be repaid through sale of reclaimed water to the Replenishment District, for spreading in facilities operated by the Flood Control District.

As Watermaster for the Court in West and Central Basins, the Department of Water Resources uses records furnished by the Replenishment District, and it levies an assessment on the parties for half the cost. The State pays the remainder.

On questions of water quality, the Regional Water Pollution Control Board seeks advice from the Department of Water Resources, the Flood Control District and the County Engineer, and it listens to testimony from the Water Associations and the Replenishment District.

Water development has been achieved through cooperative efforts of many agencies. Each has performed the task it was best able to accomplish. In no case has there been a set-back because of encroachment of one agency into the field occupied by another. The feeling has always been that the success of one, in its endeavors, has reflected credit upon all others.

The West Basin, the Central Basin and the Upper San Gabriel Valley have active water associations, including cities, water companies and large industries. All major advances in water development have been initially planned and ultimately carried out by the associations, including formation of three municipal water districts, annexations to Metropolitan, and formation of the Replenishment District.

All needed legislation and amendments thereto, have been sponsored to final enactment by the associations. They initiated the law suits and furnished the leadership needed to settle them. May their good work continue!

THE LEGISLATIVE APPROACH TO GROUND WATER*

by

Senator James A. Cobey, Chairman
California Senate Fact Finding Committee on Water Resources

Mr. Chairman, Participants in the Conference:

It is a pleasure to be here with you for a short time today. I have been asked to speak for a few minutes on the subject of "The Legislative Approach to Ground Water."

My distinguished colleague and counterpart in the Assembly, our current moderator, the Honorable Carley V. Porter, the Chairman of the Assembly Water Committee, has covered much of this field in his opening remarks. As a matter of fact, as you all know, the Assembly Interim Committee on Water, rather than the Senate Fact Finding Committee on Water, has done most of the investigation of ground water problems in California, and I personally consider the Assembly Committee's report of December 1962 on this subject one of the finest legislative reports I have ever read and certainly the best short publication on this subject. Assemblyman Porter has also originated much of the major ground water legislation in this field, and I think in the Legislature we all recognize him as our outstanding expert in this field.

He is, as you know, from Southern California. Ground water legislation in the State of California, as I am sure most, if not all of you, are well aware, is largely a Southern California matter. The

*Presented before the Ground Water Recharge Conference, University of California at Los Angeles, September 1, 1965.

Assembly under our present system of legislative representation represents predominantly Southern California. The Senate, on the other hand, being chosen on an area rather than a population basis represents predominantly Northern and Central California. It is not surprising then that most of the legislative work in this field has been done by that house which is predominantly representative of Southern California, namely, the Assembly.

For it is Southern California and not Central California or Northern California which is most dependent on ground water for its water supply. Likewise, it is Southern California where most of the critical problems have arisen, namely, the continuous and serious over-drawing of ground water basins, the intrusion of sea water into the coastal ground water basins by reason of the undue lowering of their fresh water contents, the degradation in quality of water within these ground water basins by reason of contamination and too much reuse, etc.

Given this set of conditions, it is not surprising then that by and large California ground water legislation in the past has been Southern California originated and largely Southern California in application. This is where the most critical problems have been, this is where the need for their solution has been most urgent and this is where the public has been willing to accept regulation in ground water use in the interest of the conservation of this priceless natural resource.

Accordingly, looking toward the past in contrast to Assemblyman Porter, who looked largely toward the future, I find that ground water legislation in California is by and large comparatively recent in origin, it is almost completely regional in application and it is quite limited in

scope and amount and the legislative approach that it represents has been on the whole quite cautious and empirical.

However, I will agree that the basis for a wider and more comprehensive legislative approach was laid in 1961 with the enactment of the Porter-Dolwig Ground Water Basin Protection Law. In this piece of legislation the Legislature for the first time expressly recognized that here in California the greater portion of the water we use is stored, regulated, distributed and furnished by our ground water basins, that such basins are subject to critical conditions of overdraft, depletion, sea water intrusion and degradation in water quality and that, therefore, the people of this state do have a primary interest in the correction and prevention of irreparable damage to or impaired use of our ground water basins. Consequently, in this legislation the State Department of Water Resources was directed to initiate investigations and studies of projects deemed by it to be practical, economically feasible and urgently needed to protect these ground water basins and to review projects of local agencies that such agencies choose to submit to it that have the same purposes.

Even prior to this legislation the State Department of Water Resources had as a part of its overall responsibilities begun spending substantial sums of money for ground water investigations so that it might know not only our surface water resources but our ground water resources as well. Counting the current fiscal year of 1965-1966, the Department will have spent in the last 7 years over 6 million dollars of General Fund moneys in such investigations and if the expenditures for

related work, such as quality monitoring, measurement, etc., are added, these expenditures amount to over 9-3/4 million dollars. The ground water basin protection studies made pursuant to the Porter-Dolwig Law are set forth in the Appendix to Assemblyman Porter's speech.

The effective work in ground water management and conservation has been done in California on a local basis. As the aforementioned December 1962 Assembly Report shows, outstanding work in this area has been done by the Santa Clara Valley Water Conservation District, the United Water Conservation District of Ventura County, the Orange County Water District in particular and the Central and West Basin Water Replenishment Districts. Direct legislative participation in such work has been limited to the authorization of the water replenishment powers requested by such local districts when such request has been made, notably with respect to the Orange County Water District. You will recall that in 1953 the Legislature authorized the pump tax within the Orange County Water District and the extension of the boundaries of that District to include substantially the entire overlying basin. As we all know and again as the Assembly Committee Report makes abundantly clear, the pump tax has been an exceedingly effective means of conserving the use of ground water and at the same time providing the financial wherewithal to purchase imported water so that the ground water basin might be recharged and the excessive pumping therein reduced. No fixed limits in amounts of ground water used are placed on pumpers. All that happens is that the pumper has to pay a pump tax which is measured in proportion

to his pumping. In other words, he is taxed on the cost of conserving the ground water basin in direct proportion to his own contribution to that problem. To me this pump tax seems entirely fair and equitable and it apparently has been most effective.

There have in fact been in my opinion only three major pieces of ground water legislation in California aside from the Porter-Dolwig Water Protection Law which I have already discussed. These three statutes were passed between 1951 and 1955. They all apply either to Southern California alone or a portion of Southern California. I shall discuss each of them briefly.

The first of these is the 1951 statute, Sections 1005.1 and .2 of our Water Code. These apply only to the 8 Southern California counties of Santa Barbara, Ventura, Los Angeles, Orange, San Diego, Imperial, Riverside and San Bernardino. They provide in effect that the holder of a ground water or pumping right in an overdrawn ground water basin may substitute for all or part of the ground water theretofore pumped by him water from a non-tributary source without any reduction or loss of his ground water right in so doing.

These statutes were necessitated by an adverse effect of the decisional or case law made by one of the higher courts of our State, namely, our own Supreme Court. I refer to the decision of that Court in 1949 in the case of Pasadena v. Alhambra, 33 Cal.2d 908. That decision originated the doctrine of mutual prescription in overdrawn basins under which the pumping rights of all pumpers within the overdrawn basin during the period of overdraft were held to be mutually prescriptive and therefore

equal. In deciding the extent of each pumper's right, the Court held that it was the amount of water pumped over a 5 year period and not thereafter reduced in amount for a 5 year period.

Given this rule of case or decisional law, an individual pumper in order to protect and to maximize his ground water or pumping right had to continue pumping at the highest figure he had pumped in the past over a 5 year period in order to be sure that no part of his pumping right were lost.

These 1951 statutes met the problem created by this judge-made law by providing that a pumper could use and substitute water supplied from outside the basin without losing any of his pumping rights. I hasten to add that these statutes set up an annual reporting system so that a reliable record could be had and maintained of the amount of substitution claimed under these statutes.

The second major piece of legislation was enacted in 1953. This is Section 2020 of our Water Code which grants now to the State Water Rights Board as a referee in a court adjudication the power to apply to the court for an injunction pending the outcome of the adjudication proceeding after it has filed its report as referee if it appears "that no ground water is being pumped in an amount which, if not restricted, would destroy or irreparably injure the waters of the basin due to ocean water intrusion before final judgment can be had." This law applies only to 5 Southern California counties, namely, Santa Barbara, Ventura, Los Angeles, Orange and San Diego.

The final and most important piece of ground water legislation

enacted by the California Legislature in recent years is the act requiring recordation of water extractions and diversions within the 4 Southern California counties of Ventura, Los Angeles, San Bernardino and Riverside. As you may recall, originally Santa Barbara was included but it was taken out subsequently. This Act is found at Sections 4999 to 5008 of our Water Code. Under it since 1956 each person who extracts ground water in excess of 25 acre feet in any year must file with the State Water Rights Board annually on or before March 1st of the succeeding year a notice of extraction and diversion of water on a specified form. Notices other than the first notice must state in addition to the name of the extractor or divertor the quantity of water taken from each surface and ground water source, the location of each such source, and for surface water diverted, if such diversion be above 3 miner's inches, the maximum and minimum flow diverted.

Certain sanctions to make this annual reporting system of water use within these four counties effective are written into the statute. Section 5003 provides that "No prescriptive right which might otherwise accrue to extract ground water shall arise or accrue to, not shall any statute of limitations operate in regard to such ground water in the four counties or any of them after the year 1956 in favor of any person required to file such notice of extraction and diversion of water, until such person shall file with the board" his first such notice. Furthermore, under this same section as to each person who fails to file his first notice by the end of 1957, it shall be deemed for the period from 1957 "until the first notice of such person is filed under the statute that

no claim of right to the extraction of ground water from any such source in the four counties has been made by such person and that water so extracted by such person from such ground water source during such period has not been devoted to or used for any beneficial use." Finally, "The beneficial use of water from any ground water source within the four counties in any year by such person shall be deemed not to exceed the quantity reported in the notice filed for such year."

These are not the only sanctions. Under Section 5004 "After the year 1959, failure to file with the board a notice for any calendar year within six months after the close of such calendar year shall be deemed equivalent for all purposes to nonuse for such year of any ground water within the four counties by each person failing to so file a notice within said period."

The Act also permits any person to apply to the State Water Rights Board for an investigation of the facts stated in any specified notice that has been filed and for the Board to thereafter state in writing its determination of the facts found by it upon such investigation. The costs of these administrative proceedings are paid by applicant and the interested parties are notified to furnish additional information if the Board's initial investigation indicates that its determination may differ in any material respect from the facts contained in the notice. The notices themselves cannot be used as evidence in any litigation of the facts stated therein but Board determinations shall be prima facie evidence of such facts.

This completes my very brief statement of the highlights of

existing ground water legislation in California. You will recall that Mr. Porter's committee, after its very excellent investigation of ground water problems in California, concluded that no further legislation was needed at that time and, with the exception of the legislation which Mr. Porter mentioned in his remarks, there has been no further ground water legislation since the Porter-Dolwig Law.

However, I am glad to hear that Mr. Porter's committee is going to resume their work in this field because conditions and urgencies change and in their forthcoming study in this interim they may find that further legislation is needed to enable the people of Southern California to act with the speed and effectiveness that their ground water situation may demand.

Some of you may have grown weary of my constant reference to ground water problems as being for the most part limited to Southern California. I recognize that ground water problems also exist in Northern and Central California and that the previously alluded to Santa Clara Valley Water Conservation District has pioneered in a recharge of the ground water basins programs. I am well aware that many districts in the San Joaquin Valley have successfully used their federal water for this same purpose. I also know that our distinguished program chairman, Leonard Schiff, who is one of the great technical experts in this field, is located in Fresno in Central California. Therefore, I assure you that I am well aware that Southern California has no monopoly upon ground water problems in California.

However, I would stress to you that legislation comes into

being normally only when the problem has become acute and when there is a widespread public demand for a solution. You technical experts can provide the Legislature with the indispensable technical guidance in fashioning engineeringly and fiscally feasible solutions to ground water problems but such solutions cannot take the form of statutory law unless there is also a current public demand for that.

If you will pardon a personal reference, I will give you my own experience in connection with the problem of air pollution in the San Joaquin Valley. Back in 1959 I persuaded the Governor to include the formation of a San Joaquin Valley Air Pollution Control District in his legislative program in this field and with his active support I obtained the passage of an act setting up such a district in the Valley provided the voters approved the same at the 1960 General Election. However, as that election approached I found that there was organized opposition to the formation of this district on the part of county government within the Valley who insisted that they would and could handle the problem themselves and on the part of the oil companies who were afraid of "the camel's paw under the tent." Because the opponents to the formation of this district were well financed and the proponents were not, being unorganized largely, the formation of the district was defeated by a 5 to 1 margin in the November 1960 election. This proved to me that timing is all important in the legislative approach. It does no good to recognize the problem and to work out a sound and fair solution to it if there are not a sufficient number of people really concerned about it to make the solution politically acceptable.

In closing let me say that I am tremendously interested in the work that you are doing in this Conference. I think it is tremendously important for the future welfare of this great State of ours. We all know that a sound, conjunctive use of surface and ground waters is essential if this state is to find practically all of the water that it needs within its borders. Therefore, I wish you Godspeed in your efforts, but in bringing to those of us who have the good fortune to be members of the California Legislature hereafter the fruit of your labors at this conference for enactment into statutory law, please remember that such enactment can be accomplished only if we also have a sufficiently widespread demand for such enactment. I know that in your own ways you will all do all that you can to educate the public to an awareness of the existence of our ground water problems, to the necessity for their solution in a fair and feasible manner and to the wisdom of writing certain of those solutions into our statutory law.

Thank you.

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STATUS AND NEEDS IN GROUND WATER DEVELOPMENT AND MANAGEMENT

Moderator - Lloyd C. Fowler, Chief Engineer
Santa Clara County Flood Control and Water District, San Jose

Panelists

Oscar E. Dickason
Sanitary Engineer
U. S. Public Health Service
Palo Alto, California

Howard H. Haile
Division Engineer
Water Conservation,
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Los Angeles, California

John Harshbarger, Professor of Geology and Chairman,
Department of Geology
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California Department of Water Resources
Sacramento, California

* * *

Ladies and gentlemen, the topic of our panel this afternoon is the Status and Needs in Ground Water Development and Management. The status ranges from worse than bad to pretty good, but nowhere is it really good, because we still need to provide the means for full economic management. This means the complete control through the co-operation of all concerned of the water from the source to the outflow including the intervening rocks through which the water moves. This means uniting the surface and the ground waters, both physically and legally.

We need new concepts, as Mr. Banks very effectively pointed out this morning. We need a better understanding by all concerned, including the public, of the physical relationship involved. Not necessarily to the extent that we know every last infinite detail but enough to allow a better management of our resources. Mathematical models and electronic computers will help us get close enough to the answer for many practical purposes. "Good enough for all practical purposes," because the end result is effective

economical management of our water resources.

Ground water basin management and development is made effective by solving all of the problems of ground water basins and integrating with surface water systems. The two cannot be separated for practical and economic system operation. Much of what will be briefed by this panel will be emphasized during later sessions. Our desire is to introduce some of the problems, to express the status and needs of some of the more important aspects of ground water basin development and management. However, because of the importance of these problems, we will select a few for amplification beyond the immediate status and needs.

To either effectively develop or manage a ground water basin a large amount of long-term hydrologic, geologic, economic, and engineering data is required. The hydrologic data ranges from rainfall to ground water levels to water consumption, explaining the amount of water supply available and the water needs. To be effective the data must cover the area and be of long duration. Without adequate data, efficient engineering is not possible. Mrs. Helen J. Peters will discuss the hydrologic data portion of this vast problem area.

HYDROLOGIC DATA FOR PLANNING AND MANAGEMENT OF GROUND WATER BASINS

By

Helen J. Peters
General Staff
Department of Water Resources
The Resources Agency
State of California

Hydrologic data is big business. Over one-half of the cost of ground water investigations and project planning studies in the State Department of Water Resources is for this item. Any phase of work which constitutes this large share of costs deserves our serious attention at any time, but particularly now as competition for the resources planning dollar is growing.

We find that there are two general types of data being collected: The long-term hydrologic data and the short-term investigation data. Each of these general types may include several specific kinds of data such as ground water qualities, water levels, water recharged, and water pumped.

Long-term hydrologic data is used for selecting hydrologic study periods and for determining hydrologic quantities over mean and/or study periods. These study purposes may require precipitation, surface stream, and ground water records of 10 to 30 years in varying degrees of detail of coverage. Because the data is time-related, it must be collected at the time the phenomena occurs and cannot be obtained at the time of a specialized study.

Data collected as a part of a special study or by operating agencies is called for by the specific problem, is generally responsive to the pressing immediate needs and supplements the long-term data.

Some problems are common to both types of data, but I will today emphasize the needs of long-term data because it alone constitutes one-third of the Department's total planning costs and has been given less than its fair share of professional attention in the past. Those of you who are users of long-term data have a real interest in this type of data even though you may not be directly involved in its collection.

Ground water development project planning and management will be accomplished through the efforts of all levels of government and by individuals. Smaller public agencies and private engineers are not usually in a position to provide their own long-term data and a state-wide network must make available the appropriate data when it is needed. The problem then lies in defining what "appropriate data" is and deciding "when" it will be needed in order to define the long-term hydrologic data program to meet California's needs.

In defining "appropriate data" we must first accept that ground water project planning takes the same form as other resource development planning and proceeds through the same general phases. A ground water "project" may be an operational plan with little or no physical works as contrasted to a surface water project which usually has evident physical expression.

The first phase of planning is usually an evaluation of the hydrologic resource followed by a preliminary examination of the resource and the physical capabilities available to develop that resource. If sufficient possibility exists for a project, a reconnaissance level project investigation is usually conducted and as a result of that investigation specific projects are selected for a project feasibility study. Only after such a feasibility study is a water project, including a ground water project, implemented.

Requirements for hydrologic data at each of these levels of

study must be defined in terms of reliability of results. The definition of need in all cases involves type, intensity, and length of record which must have preceded that study. The criteria which determines the amount or degree of detail of various kinds of data must be tied to the needed reliability of the answer at each level of study.

The earlier ground water project studies, those of resource evaluation and preliminary project examination, must be sufficient to assess the potential of the resource and indicate the possible projects for protection of the basin and management of the ground water and the basin storage capacity. The data requirement is lower because reliability of the studies is expected to be lower.

As we proceed to the ground water studies at the project reconnaissance level we begin to encounter data requirements which are tied to the development and validation of a ground water basin model. Reliability of product, and therefore amount of data, goes up. Project feasibility study data requirements are usually of the same type required for a reconnaissance study but of greater intensity in order to provide greater reliability of the hydrology answers.

In addition to defining the hydrologic data grid and period of record needed for each of these levels of study, we must also foresee when the studies will be made at each level in each area of the State. The determination of the "when" portion of defining our future data needs involves the comprehensive staging of all future water projects in an area. The staged plan indicates the point in time at which a ground water project takes its place with surface water projects in the complete water resource development system.

With a plan for staged water development in hand and with definition of the reliability required at each level of project study we begin to build a framework against which we can evaluate and design our long-term data program. A plan for staged water development for California is scheduled for publication annually beginning in 1966. However, we have not yet developed the criteria or guidelines to define the needed reliability required for each of the previously mentioned levels of study. Development of such criteria for hydrologic data, and for the geologic information to be discussed by Professor Harshbarger, is of immediate concern. It is prerequisite to evaluation of what is being collected in order that the State can "fill in the gaps" and select

that local agency data which should be published and preserved as part of California's hydrologic resource data.

In addition, I would like to mention two other major problems which must be solved.

First, the problem faces us in allocation of total available funds. As engineers we are never satisfied with the data that is available, but it is not possible to gather more and more data for expected future needs without balancing those future needs against the present need for resource investigations or project planning studies. We feel that this problem needs to be approached by studies which would determine the economic benefit of having certain degrees of detail of data available at various stages of planning balanced against the results of those planning studies.

Secondly, we face the problem of new techniques being developed in the ground water field which may require kinds of long-term hydrologic data which we do not now collect. We experienced this problem recently with the advent of ground water basin modeling techniques. We may be faced in the future with basin management planning using stochastic or probabilistic hydrology which would require strengthening data on stream loss rates, rates of movement in the zone of aeration, and others. We can only remain alert to new ideas and readily adapt our programs to these types of changing requirements.

In closing, I want to re-emphasize that the approach to managing the long-term hydrologic data program for California is dependent on defining the time when various reliabilities of evaluated data are needed. Each data network must be carefully designed to obtain a specific product--and that product is the where, what, when and why of ground water occurrences, volume, and movement. This, of course, is tied to parallel geologic knowledge.

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Moderator: Thank you, Joyce. Another very important aspect of the data problem is the collection, reduction, and interpretation of geologic data. The geologic data explains how water gets in and out of the ground water basin and why the ground water acts as it does underground. Geology can tell us a lot about what we can do and cannot do in developing and managing the ground water basin. For example, the extraction of ground water in excess of the transmissive capacity from a point of

good water quality recharge can result in the invitation of saline water intrusion or excessive lowering of ground water levels. Professor Harsbarger will discuss some of the basic aspects of geology used in the development and management of ground water basins.

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SOME QUANTITIVE ASPECTS OF GEOLOGICAL TERRAINS AND GROUND WATER PRODUCTIVITY

By

John Harsbarger
Professor of Geology and Chairman, Department of Geology
University of Arizona

There are many aspects of geology that we could discuss in relation to ground water. I would like to concentrate on one idea, one thought, which is on the quantitative aspects of geological terrains and ground water productivity.

First let me say that there has been much information collected on micro-details by the geologist--such as finding fossils and describing them, determining the age of the rock, such things as grain size distribution, the composition as to the minerology, as to the source of the rock itself, as to its characteristics, and of course the depositional history. These pursuits are always a lot of fun because you need the facts or the evidence to corroborate the hypotheses. Similar situations are also true in respect to the tectonic modification of particular rocks, but this information is of limited usefulness in ground water basin management.

Also, I have found and believe (and I hope some of the geologists here will not be offended with this) that a lot of geologists fail by their reluctance to project the big picture--in other words, they fail to generate megathinking on the quantitative aspects of geological terrains with particular reference to ground water productivity. I believe that the ground water geologist must do this sort of thinking. He has to first define the geological terrain, the ground water reservoir, which is necessary in order to make any kind of assessment of the regional hydrologic system that is in turn required to get on with the development and planning of this particular reservoir.

I will take a few moments to review the general classification of rock reservoirs, keeping in mind that we're trying to think in terms of three dimensions. We could make a simple twofold division of rock types well known to geologists and ground water engineers--one of consolidated, and the other of unconsolidated. Under the consolidated class we include carbonate aquifers or reservoirs and sandstones. These latter are well cemented for the most part and the sandstone aquifers probably constitute our principal consolidated aquifers. In the unconsolidated class, or those made up of loose granular materials, we think of the alluvial materials such as found in many of our inter-montane basin in the interior areas, the coastal marine deposits such as you're quite familiar with here in Southern California, and of course in other shoreline areas, the glacial deposits in the Great Lakes area and Eastern United States.

In Ground Water Basin studies we need to know the boundary and barrier conditions. Slide one (not included with paper) illustrates the simple relationship of this effect. On the right side is the impermeable barrier of the ground water basin; on the left is a stream which recharges to an essentially homogenous and isotropic porous media except for the hard rock barrier on the right. By imposing a pumping regimen one can see the effect of the barrier, the rapid decline of water levels, and the effect of recharge maintaining a high water level. Many of our ground water basins have barriers formed by structural modification. Indeed they are confined by the structural geological features that have been wrought by the forces of nature.

Many of our basins are sedimentary basins. A simple sandwich model shows the effects of multiaquifers or layers of variable permeability. I think you can see the areas of large permeability, the coarse grain size portion, the main matrix being the medium grain, and then the light band is a very fine grain material constituting boundary condition on the very bottom. This is a simple simulation of many of our multilayered aquifers both in the alluvial basins and plateau areas which shows the effects of these rock types or distribution and boundary geometry on the flow behavior as water moves through under steady conditions. Here is a view of a claystone, the Chinle Formation, found in the Petrified Forest area, which gives you some idea of an aquiclude. The next slide shows the effect of tectonic modification on a consolidated rock; the tectonic forces break these rocks and develop a secondary void space. One can observe the magnitude of the fracture or joint systems which is related to faulting. Geologists commonly talk in terms of competent and incompetent rocks--sandstone and also carbonate rocks would be competent rocks, the Chinle Formation would be an incompetent one. The development of secondary permeability

is of great concern to the hydrogeologist and the ground water engineer, and the degree of cementation is also a significant factor.

How do you measure cementation? How do you project the distribution of cementation? I've learned recently that a particular oil company stopped operations in a certain area because their zone of interest in potential reservoir rocks was found to be tightly cemented with bisillicate, thus reducing the hope of finding oil. The same thing is true in ground water, and how you predict the degree of cementation I still don't know. This is one aspect we need more study on.

The next slide gives us some ideas on the occurrence of karstification. These features are usually associated with carbonate rock, but here I found some interesting outcrops where we have similar features in sandstone. I firmly believe that much of the material removed in the development of the harst was related to an initial fracture system caused by tectonic modification. In the solution openings there is flow similar to surface water flow, that is, open channel flow in the subsurface regime, and it has a very direct relationship to productivity and transmissive characteristics of the rock. The next slide shows some karstification in carbonate rock, which is quite common. Here this is of interest because the water level in this particular carbonate aquifer is only a few meters below the present land level. There variations in thickness is a principal concern. As you well know, the transmissive character is directly related to the total thickness of the saturated zone and the permeability of the rock media.

Now a subject which I'd like to have a lot of time to discuss, mainly because I know very little about it, is the ratio of horizontal to vertical permeability. This factor has not been given the consideration it deserves when you're talking about ground water movement, particularly when you're dealing with recharge into the aquifers. In many of the rock types the horizontal to vertical permeability ratio is in the order of 1 to 5, perhaps less in some of the more isotropic materials, but as you depart from isotropic materials the ratios become 10, 50, 100, and even 1000. These higher ratios are typical of the reservoirs from which we produce ground water. There's very little quantitative data on these parameters and we need to do something about obtaining more information.

We also need to know more about the vertical distribution of water, that is, the head in the various systems of our multiple

aquifers. I'd like to make a plea for the greater collection of data regarding these points because I believe that we would know more about the fluid behavior in our systems and about the characteristics for production if we understood more about the relative heads in our aquifers. These data can be collected, but it is a time-related data and the time to get it is when you're drilling a well. This is not easy as those who work with drillers know very well.

In conclusion, let me say that we need to have a quantitative knowledge in three dimensions of our geological terrain. This will permit a better analysis of the hydrologic system. Only when we understand the hydrologic system can optimum management be undertaken. The analog model hardware is available, but the data that we feed into it has a direct relation to the preciseness of the answer. The field geologist knows the basic geologic characteristics well. He understands the terrain. But he must understand the interrelationship between geology and fluid flow and thus be able to meet the challenge to define the forest instead of becoming lost in counting the trees. He must assume the role of a hydrogeologist and think in quantitative terms; he must be able to make cause and effect system analyses. Finally, we must assume the bold approach, to explain the hydrologic system and then determine the significance or insignificance of a geological anomaly rather than become entrapped researching the interesting curiosities of the anomaly.

* * *

Moderator: Thank you, John. One of the important aspects of developing the potential of a ground water basin or improving its management is the recharge characteristics, both as to quantity and location. More effective use of the ground water basin can be obtained through the proper use of natural and articicial recharge measures to combat lowered ground water levels, sea water intrusion or water quality degradation, or land subsidence. The management of a ground water basin cannot be complete until the full use of its capabilities has been made effective. For example, in the Greater Los Angeles Ground Water Basin a major portion of its forebay area is not effective because of the lack of recharge; the surface of this area has been essentially paved. What a challenge to find a way to use this vast water storage and transmission area! What would be the most economical means to recharge this area? Would

it be wells, leaky pipe systems, or how about knocking holes in all the basements in metropolitan Los Angeles and flooding them? The recharge problem exclusive of this controversy but including the several types, effectiveness, experiences, and needs for further studies will be reviewed by Mr. Howard H. Haile.

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GROUND WATER RECHARGE EXPERIENCE IN LOS ANGELES COUNTY

By

Howard H. Haile
Division Engineer
Water Conservation Division
Los Angeles County Flood Control District

I will comment on the experience of the Los Angeles County Flood Control District with their spreading and injection facilities, and some of the problems associated therewith. The major effort of our water conservation program is involved with the surface spreading of local, imported, and reclaimed water and the development and operation of barriers to sea water intrusion. Both the spreading operations and the barrier activities have intensified in recent years, particularly the barriers in the past year and a half. New barrier facilities placed in operation have increased our injection rate through recharge wells to where we are now injecting about 70 cubic feet per second into the ground. This is about 10 times the amount a year and a half ago. Our surface spreading program for this year anticipates the spreading of about 116,000 acre feet of Colorado River Water and approximately 13,600 acre feet of reclaimed water. These latter amounts, of course, are in addition to such spreading of local water as is available to us. Unfortunately we have experienced less than normal runoff in recent years with 16 out of the past 19 years being below normal in rainfall.

The spreading of imported and reclaimed waters involve the close co-operation of a number of local agencies and we have enjoyed such co-operation throughout my experience with this work. We feel we have a successful water conservation program going. We feel that we can do the job we need to do, but we also feel, as is

usually the case, that there's room for improvement. Some of the problems associated with the operation of our spreading grounds for instance have been with us for a number of years and still remain to be solved. Others are of more recent origin.

Some perennial problems for which answers are still being sought include the handling of silt in local storm waters. The silt content of storm runoff frequently amounts to 2500 to 5000 parts per million of silt and of course even higher in certain circumstances. This quantity of silt carried into surface spreading facilities will rapidly seal off the percolation bed and render the facility ineffective. We have made some progress in this regard. The use of flocculants and coagulants offer some promise, however, we at the Flood Control District have not yet found a completely satisfactory solution to this problem.

Additional effort must be directed to the development of more efficient methods of ground water recharge and replenishment to reduce the land area required for spreading grounds. We have about 1900 acres devoted to spreading grounds in Los Angeles County, and with the competition for land and the values of land as they prevail here today, it's absolutely essential that we use it in the most effective manner possible.

Also in an area such as southern California, biological nuisances become serious problems when water conservation facilities are closely surrounded by highly developed commercial and industrial areas. Control of such insect pests as midges and mosquitoes is a constant concern of the spreading grounds operator if he is to conduct his program in harmony with his neighbors. Noxious weeds, particularly of the aquatic type that are normally relatively scarce in this area, have presented some difficulty. An example is a plant known as alligator weed which has established itself in the Whittier Narrows area. Our agricultural commissioner tells us that it's the only infestation west of the Mississippi. This weed not only tends to choke delivery channels and channel subdrains but has spread into debris deposits that accumulate in various areas of our system. To prevent its spread to other areas the agriculture commissioner placed a quarantine on materials infested with this weed thus the removal of debris is subject to rigid control. We have been able to incorporate some of the coarser material into our spreading grounds as part of a regrading program and we have arranged to place some of this material into commercial docking areas which are surrounded by retaining walls and surfaced over.

With regard to barrier operations, it was previously noted

that these operations have increased in scope, and we perhaps have not fully realized all the problems that we may yet encounter. One of the first problems that we ran into during the first operation of the Manhattan Beach Barrier Test was that of well-clogging and we still have not found a satisfactory solution to this difficulty. Although we are using water of drinking water quality and clarity and chlorinating it with about one and one-half parts per million of chlorine, we nevertheless are faced with the prospect of having to redevelop our recharge wells on the average of perhaps once every two years. This is a relatively expensive operation since it may cost from 4 to 6 thousand dollars to redevelop a well. We believe we are making progress toward a better understanding of the causes of clogging but have not yet found a way to minimize it to a satisfactory level. Aside from the clogging aspects barriers are, by their nature, relatively costly to operate, and the challenge is always present to find ways to reduce the cost of operating these facilities. We are studying the prospects of automating the barriers either all or in part as a cost reducing possibility. We are also investigating different methods of redeveloping our barrier wells. One of the most serious problems that confronts us is the disposal of water when we have to redevelop a well. During such operations it is necessary to pump the well at rates of perhaps 1000 to 1200 gallons per minute. These disposal operations take place in highly built-up areas where drains or other means of disposal are not always readily available. Possible answers to this problem are either the construction of separate disposal pipelines which we have done in some cases or possibly treating the redevelopment water to make it suitable for reinjection. We have, of course, uncovered some problems in design in our new barrier facilities. I'm happy to say that they do not appear to be terribly serious. The barriers are working and are accomplishing the purpose for which they were designed.

The foregoing are but a few of some of the more important considerations that affect the water conservation program in our local area. Undoubtedly other people in other areas will find some of the problems mentioned common to their operations but they will certainly find new and different situations to be dealt with, too.

* * *

Moderator: Thank you, Howard. We will skip lightly past the problem of transmission of ground water, that is getting the water from the point of recharge to the point of use, and of getting ground water out

in the proper quantities and locations by merely noting that these problems, too, need to be solved in ground water basin development and management.

As our water requirements quantitively approach our supplies, better use must be made of the water available. Water now wasted must be reused. One of the promising methods for reusing water is to recharge the ground water basins with the effluent from sewage treatment plants. However, is the public at large ready to knowingly accept the fact that their water supply is used water? And can reuse be safely accomplished by ground water recharge without extensive treatment? And what types of treatment may be required to maintain the public health standards? In spite of the very material advancements made in this area over the past few years, there is still lots of room for questions and answers here. Mr. Oscar E. Dickason will discuss some of the public health aspects of ground water basin development and management.

* * *

STATUS AND NEEDS IN GROUND WATER QUALITY MANAGEMENT

By

O. E. Dickason
Sanitary Engineer
Division of Water Supply & Pollution Control
U. S. Public Health Service

The water quality problem in the field of ground water development are as many and diversified as the water quality problems involved in the management of surface water resources. Standards must be set and means made available to water resources managers, whereby they can effect the optimum utilization of these limited resources as ever increasing demands are placed on the available fresh water supplies. One very important factor in the management of these resources is the maintenance of desirable water quality standards. The status and needs of just a few of the areas concerning the protection of the ground water quality will be covered here today.

One source of recharge water for ground water is renovated

waste water. Use is already being made of this source of water in southern California where several pilot plant studies have taken place or are in progress. In areas where the importation of water is not economically feasible and present resources are running short, the use of this source of water is certain to increase. Even in areas where imported water is being made available, such as southern California, the water resources manager must make maximum use of the costly imported water, and this maximum use will include the reuse of waste waters for ground water recharge. In the light of this practice, there is a need to develop treatment criteria, sampling criteria, and monitoring criteria to insure the safe use of these waters.

Various advanced waste treatment pilot plant studies are being conducted throughout the country. From these pilot investigations, it should be possible to establish treatment criteria for the renovation of the waste water. These criteria will vary according to the use of the water. For example, water for direct reuse would, more than likely, require different treatment than to be used for ground water recharge or for that used solely for recreation purposes.

More than treatment criteria, however, a better set of criteria is required for the finished water. These criteria will also vary with the planned use of the treated water. For example, we are interested in developing criteria for the use of reclaimed water for ground water recharge. The criteria here may vary depending on the recharge methods (deep well injection or surface spreading), nearness of the recharge site to the potential users of the recharged water, and the type of formation being recharged. These criteria should be established in order to protect the quality of the recharged ground water body and should not be treatment or conditioning criteria for the preservation of the recharge site. The interest here is the prevention of the movement of bacteria, virus, and other harmful organic and inorganic materials into the ground water. With this in mind, it is necessary for the administrators and engineers to work closely together to develop a sampling program which will truly characterize the reclaimed water prior to recharge. Here, monitoring techniques are needed that will allow for the rapid characterization of the water so that the waters may be bypassed from the recharge site when an unobserved breakdown occurs in the treatment process. Only by these means will it be possible to prevent recharging with waters which contain undesirable pollutants. In this case, it would be desirable to find some test which can be conducted faster than either the standard coliform bacteria or virus tests and which would be indicative of the safety of using the water for recharge.

A second problem to be faced in the future is the disposal of residual wastes from interior basins. As the consumptive use of surface waters increases, the availability of dilution waters to accept treated wastes decreases. As these dilution waters continue to decrease, the maintenance of the quality of these surface waters will eventually require more advanced waste treatment methods. One of the problems associated with the use of advanced waste treatment methods will be the disposal of the concentrated waste effluents from these plants. Coastal areas may meet this problem by discharging the concentrated wastes to the sea. However, this alternative will usually not be economically feasible for cities and industries located in interior basins. In some areas, waste discharge to a water course is nothing more than a form of recharge by surface spreading. As the possibility of pollution occurring by this practice is quite obvious, care must be exercised against the accidental impairment of the ground water quality.

Alternatives to discharging to watercourses include injection into subsurface formations, placement in underground cavities, and surface spreading. It is with these matters as well as with the discharge of concentrated wastes to dry stream beds that we must be concerned. In anticipation of this, an inventory should be made of the extent and hydraulic characteristics of deep aquifers, locations of underground cavities, and the location of potential sites for the creation of underground cavities by nuclear or other means. Thus, planning for this eventuality may be done in an orderly manner. That is to say, when the time comes to consider the various alternatives, data will be available which will permit the selection of the optimum alternative compatible with the maintenance of the desired ground water quality. In basins where the inventory shows that local disposal sites are not available, the alternatives of wet oxidation, incineration or export of the waste from the basin must be evaluated.

The Central Valley of California is an example of this potential problem. Predicted demands placed on the surface waters in this basin will reduce the present flow of water to San Francisco Bay significantly by the year 2000. Plans are already underway for a master waste collection system in the southern half of this basin to remove irrigation drainage waters as a means of protecting the water quality. Many of the present conflicts concerning the final means of disposal of these wastes could, undoubtedly, have been more efficiently handled if the problem had been recognized and approached at an earlier date. This situation serves as an example that we should not wait until the problem is upon us to find the solution.

Another area where we could make increased use of the newer analytic tools available to us is in the field of digital computers. For example, a mathematical model employing a digital computer has been developed to study the surface waters in the delta area of the Sacramento and San Joaquin Rivers. Other models are under development for the Lost River-Klamath River Basin in Oregon and California, as well as for other basins throughout the country. These models have been designed to simulate the hydraulic characteristics of the system under investigation and are at present being developed to simulate water quality characteristics of the system. With such a model, it is then possible to determine quality characteristics at any point in the system under various hydraulic and waste loading conditions.

In ground water management, such a model could be used to optimize the utilization of imported water for ground water recharge, or to determine the best sites for recharge of reclaimed waters to prevent a build-up of dissolved solids in the ground water. A wide variety of such ground water management problems could be handled with a mathematical model of a ground water system. For example, such a model could be used to determine the optimum location of recharge sites to maintain given ground water levels as well as given dissolved solids levels, using different water sources of varying quality. The computer would not only determine the optimum location but would also be available to make rapid decisions as the various factors which determine the recharge location vary during the year. In addition, the mathematical models programed for digital computers with their ability to handle water quality considerations could also be used to complement analog models.

Another service performed by computers is the storing and retrieval of ground water quality data. The STORET system developed by the Public Health Service is a system for the indexing and storing for rapid retrieval of biological, chemical, physical, and related data for surface and ground waters. Water use data as well as waste discharge data also are included. Using this system, it is possible to extract all pertinent data for a study in a given basin without the time consuming task of sorting through mounds of unrelated data. The advantage of having all data collected for a given basin located at such a central "clearing House" is immediately apparent. First, it eliminates the need of searching through the files of a number of agencies to get the desired data; and, if properly maintained, it insures the availability of all pertinent data for any particular study. Going further, one can visualize a co-ordinated system using mathematical models and the storage and retrieval system whereby optimum solutions for any given ground water quality standard could be developed on a continuing basis.

In surface water management, this may be carried so far as to have automatic sampling equipment with telemetering devices to feed up-to-the minute data to the computer which could then make decisions to release water from reservoirs, to change waste discharge patterns, and in some cases could be used to alert downstream water users of changing upstream conditions. Although nothing quite so sophisticated would be necessary for ground water management where changes are not as rapid as they are in surface waters, it certainly indicates to what extent computers may be used in the management of water resources.

These are only a few of the areas where advancements may be made in the area of ground water management. I am certain that tomorrow's panel discussion on the quality aspects of ground water use and management will more completely cover this topic.

* * *

Moderator: Thank you, Oscar.

After solving the problems of hydrology, geology, recharge, water quality, and engineering services, our ground water basins are only effectively developed and managed if they are economical operations. What determines economic operations? Can the ground water basin be operated alone? Certainly not. It must be physically and economically--and legally, too--united with surface water systems. The economical analysis of united surface and ground water systems can be extremely complex and subject to new concepts yet to be evaluated and accepted. For example, is there anything economically wrong with the overdraft or direct mining of a ground water supply in order to establish an economy that can afford corrective measures rather than trying to limit the development in the basin to the so-called safe yield of the area? Is it economically reasonable to maintain vast amounts of ground water in storage areas in upstream basins so that downstream areas can be provided with a limited natural outflow? How do you evaluate the economic value of water quality? These and many other economic problems can be analyzed objectively but naturally are made more complex with vast problems of political and legal implications. The political and legal problems we desire to leave to others to discuss. Mr. Frederick L. Hotes will present some of the economic considerations found in ground water basin development and management.

ECONOMICS IN GROUND WATER BASIN DEVELOPMENT AND MANAGEMENT WITH REFERENCE TO STATUS AND NEEDS IN GROUND WATER DEVELOPMENT AND MANAGEMENT

By

Frederick L. Hotes
President and Chief Engineer
Uniconsult, Inc.
Lafayette, California

Mr. Moderator, I note that a full panel presentation on the "Economic Aspects of Ground Water Use and Management" will be given tomorrow morning as part of this conference program. Some of what we outline here as "needs" in this area therefore, hopefully, may be reported subsequently as "status". Nevertheless, it is useful for those of us in assembly here, panel and audience, to highlight what to us are the more important immediate questions, so that we can seek the answers thereto by both formal and informal discussions during our proceedings, and to help get action programs started to obtain answers where they are not yet available.

My presentation will be under three meain headings:

I - Economic Factors
II - Analysis, Evaluations, and Formulation
III - Other Problems

Before proceeding to the specific discussion of details, it may be worthwhile to note that Samuel Butler once observed "that the art of living is in forming adequate conclusions from inadequate evidence". How true in ground water studies!

I. Economic Factors

No economic study can be made without reasonable data on costs and benefits. (Benefits sometimes are described more aptly as returns or revenues). Generally speaking, we find it easier to develop cost figures than benefit figures, but I find that there are several cost factors, or elements of cost, which can stand improvement in reliability and accuracy.

Wells

Consider the very basic elements of a ground water well.

We can estimate fairly accurately the cost per foot of drilling a well of a given diameter, installing the casing, developing and testing the well, buying a pump and motor, and purchasing electric or petroleum energy. I am much less satisfied with the justification for the figures used for annual maintenance and replacement costs and economic life for various components. My impression is that a lot of arbitrary data is still utilized in this regard, primarily because it is "in line" with previous estimates. There is a need for the collection and statistical evaluation and reporting of data on maintenance and replacement costs and the economic lives of wells and components, including time-decay characteristics.

Water Quality

For some time water quality standards for both irrigation and municipal and industrial purposes have been recognized and reported. These standards have been of some importance from a physical standpoint but have been of limited usefulness (if not worthless) for the purposes of economic analysis. No economic tag can be placed on the usual classification categories, and whenever an economic evaluation or comparison has been made (which is seldom) the basic data, rather than the categories, was, of necessity, utilized.

Irrigation

It is my understanding that recently progress has been made in reporting relationships of the yields of various crops to total salinity of irrigation water. This relationship should be expanded to indicate expected yield levels for various levels of salinity of soil saturation extract or drainage water, and for various typical soils. Such information will make it much easier for most of us to estimate the relative costs and benefits of using a particular water for irrigation.

M & I

Hardness of water has provided a means of economic comparison in several instances of M & I water use, but even here improvements in cost estimates of required softening measures and resulting benefits can be improved. Data on the variation of economic value of other M & I quality indices with change in concentration is minimal or nonexistent. With water quality aspects growing in importance, at least in a qualitative way (public and press)

the need for specific economic valuation exists, and work should be performed and reported in the very near future. Is there such a thing as a physical quality limitation without an economic value? (Answer -- No)

Recharge

Much more information has been made available in the last few years on ground water recharge costs, for both spreading and injection well operations. Continued progress should be encouraged, especially to develop lower-cost injection methods.

Redevelopment or Renewal of Wells

Many formerly good wells fail by reason of clogging of the well casing or adjacent formations. Costs of redevelopment, correctly identified as to capacity regained, period of effectiveness, and time-decay characteristics are needed so that such methods may be evaluated economically.

Value (Benefit) of a Unit of Water

Whether an opportunity value or a monetary value, each unit of water, whether in storage above or below the ground or at a point of usage, has an economic value. While its absolute economic value may be of academic interest only, its relative economic value is of significance in most real situations. Determination of such relative economic value is often highly controversial, i.e., relative worth of water for agriculture or industry. While many studies have been made, intending to show that a unit of industrial water is worth many times an identical unit of agricultural water, all of these which have come to my attention have fallen short of being truly conclusive; primarily in failing to consider fully multiplier and secondary effects, and the inter-relationship of industry, agriculture, and the total economy. There is a need here for a highly sophisticated, yet practical and authoritative study of the relative value of industrial and agricultural water, for use in national and regional planning and operations where water allocation may be important. Fortunately, in the majority of cases this point is not yet a significant issue.

II. Analysis, Evaluation, and Formulation

Turning now to the somewhat more glamorous and prestigious problems of analysis, evaluation, and formulation of ground water basin plans and programs, we come first to the question of just what do we mean by an economical solution or operation, or the more economical.

Economical Solution or Operation

None of us would knowingly advocate an uneconomical solution to a problem. We also can agree that the economical solutions which we recommend are primarily solutions which appear to be economically justified and financially feasible.

We may be a little less certain that our recommendations represent the most economical of many possible solutions, because of the multiplicity of possibilities. However, the advent of the "computer age" gives us much more assurance in this regard, as the number of possible combinations which can be examined has been expanded many fold, even for complex problems involving multiple uses and conjunctive operation of surface and ground water reservoirs. Given reliable input data, our technicians can compute benefit-cost ratios and other economic and performance criteria quite rapidly.

I wonder, though, if we fully answer the recommended tests of "Why do it now?" and "Why do it at all?" The conventional benefit-cost ratio index does not, by itself, give a sufficient answer to these questions. I believe that more use should be made of the calculated rate of internal return, and comparison made of this figure with the cost of money, the risks involved, and alternative investment returns for the same money. The mathematical relationship of the benefit-cost ratio and the internal rate of return is recognized, but the significance of the latter when considering the expenditure of public funds has been underemphasized and even ignored for too long. I submit for consideration the thought that both the benefit-cost ratio and the internal rate of return should be included in feasibility reports.

Proper Discount Rate

The proper rate of discount to be used in calculating benefit-cost ratios and other economic calculations is also highly controversial. With the availability of the computer it would seem appropriate to test the sensitivity of results by the use of two or more discount rates. Arguments over the relative merits of the social rate of discount, the natural rate of interest and the private rate of interest might thereby be more meaningful, or minimized.

Problems Requiring Sophisticated Economic Research and Study

Some of the most critical and better known problems of

ground water development and management deserve special economic research and study. They are:

1. Comparing the cost of a surface distribution import system to preserve or replace a deteriorating ground water supply with the alternative of recharging the basin.

2. Under overdraft or mining conditions, determining the permissible rate of extraction and/or the economic life of the ground water basin.

3. In a basin being operated under "safe yield" criteria, determining the economic merit of changing to a sustained overdraft condition.

4. Deciding whether a special area or group such as an upstream area should be required to maintain vast amounts of unused ground water in storage so that downstream users can continue to be provided a limited historic natural outflow.

5. Determining the compensation for the taking of a vested right such as that of the downstream users in No. 4 preceding. Vested interests are too often thought of as unjust interests. We should recall that vested means established by law as a permanent right. The American way is to respect the law and the rights, and to provide just compensation when such rights are taken for a higher use.

In each of these instances a good decision may depend upon the economic significance of the proposals or alternatives. Certainly legislators would, in the long run, find such information of great value.

The question of "To mine or not to mine," among others, needs basic data to be obtained only from the development of a complete basin income account with economic input-output studies. Such a study should cover the effects on both the larger community and the individual ground water pumper.

III. Other Problems

Recovery of Costs

Several alternative methods of recovering costs of a public district engaged in recharge efforts have been advocated: Pumping Tax, Ad Valorem Tax, and Land Tax, among others. Good economic studies and reports would aid both officials and the electorate to make more informed choices than some of them have had the opportunity to do in the past (i.e., identification of beneficiaries, over-all community benefits).

Knowledge of Economic Terms and Techniques

Finally, I want to acknowledge the contributions of the economists to the solution of ground water problems. I have the impression that their role has been an increasing one over the past 15 years--that they have learned the more important elements of geology, hydrology, engineering, and law, more rapidly than the other disciplines have learned the terminology and techniques of economic analysis. The economic evaluation is as important as any other, and yet do we not tolerate imperfect knowledge of this field more casually than imperfect knowledge of the physical and legal features of a ground water basin?

Those technicians who have not already started, should expand their reading to periodicals such as the Journal of Land Economics, Journal of Economics, and review the many excellent papers and books written on the economic aspects of water resources. This will help overcome what to me is an unfortunate weakness among so many of us in this field.

Lest the professional economist feel too content, I hasten to add there is a real need for them to translate their presentations into understandable terms for farmers and the public. I have the impression that they work primarily for the top leadership only. Yet we should recall the words of Carley Porter as to the source of impetus for acceptable ground water legislation--the people.

* * *

Moderator: Thank you, Fred. Unfortunately, because of the lack of time, we will not be able to entertain any audience

discussion of the presentations that have been made. I would like to thank each of the panelists for their fine presentations and suggest that if you have questions or wish to discuss further these subjects please contact us.

GROUND WATER RESEARCH AND MANAGEMENT TECHNIQUES

Moderator: Leonard Schiff, Research Leader
Fresno Field Station, Agricultural Research Service
U. S. Department of Agriculture

Yona Kahana, Deputy Director
Water Planning for Israel, Ltd.
Tel Aviv

Robert A. Skinner, General Manager and Chief Engineer
Metropolitan Water District, Los Angeles

Verne H. Scott, Chairman
Department of Water Science and Engineering
University of California, Davis

Ernest M. Weber, Senior Engineering Geologist, Southern District,
California Department of Water Resources
Los Angeles

Harlan H. Zodtner, Physicist
Plowshare Program, Lawrence Radiation Laboratory
University of California, Livermore

Leonard Schiff: I have had the privilege of discussing water problems and solutions, research, and management techniques with our panelists on several occasions. These panelists are well-qualified leaders in their fields and I encourage you to seek their counsel and talk to them when opportunities arise. Because of the technical nature of our subject our panelists have prepared papers for presentation and they are included in these proceedings. I believe these papers are informative and I encourage you to read them.

It is proper that we start with a man who has come a long way to exchange ideas with us, a man who recognizes the need to conserve water and to use and manage water efficiently. I've had the privilege of discussing these subjects with our visitor in my office on a few occasions. He will talk to you on management of ground water. It is with particular pleasure and a privilege for me to present Yona Kahana, Deputy Director, Water Planning for Israel.

Over the years I've had the good fortune to know and exchange ideas with our next speaker. He has made and is making valuable contributions in this field. He now serves as Chairman of the Department of Water Science and Engineering, University of California, Davis. He will discuss research activities conducted on the operation of wells, recharge by wells, water and salt balances in a two aquifer system, and in predicting water quality changes in percolating water. It is my privilege to present Verne Scott to you.

We have with us a representative of the Metropolitan Water District, a district vitally concerned with many aspects of recharge, development, and management of ground water. Our next speaker will summarize salient points concerned

with the economics and acceptability of ground water recharge. It is a pleasure for me to present Robert Skinner, General Manager and Chief Engineer of the Metropolitan Water District.

I've been on a number of programs with our next speaker. I know you are going to hear an interesting and informative account about the action of a ground water basin. So-called simulation techniques offer us much insight into the operation of a ground water basin and thus development and management ideas. It is with pleasure that I introduce to you Ernest Weber, Senior Engineering Geologist, Southern District, California Department of Water Resources, Los Angeles.

I believe you will find the next part of our program somewhat startling and enlightening. There is a tremendous energy available to us. The energy of nuclear explosives. I believe we will make a mistake if we do not take a good hard look at its possible application to the field of water resources. I asked our next speaker to describe a film that I had seen, indicating the huge craters that are created by nuclear explosives and to discuss the possible use of these craters in ground water recharge and to mention other applications. I've had the pleasure of working directly with our next speaker on some aspects of the problems involved in recharge and it is a privilege for me to present Harlan H. Zodtner, Physicist, Plowshare Program, Lawrence Radiation Laboratory, University of California, Livermore.

wish to imply that the highest safe yield was the goal. There certainly exists an optimum, that may change from place to place, beyond which it is not desirable to permit intrusion of salt water.

In Figure 2 you see an intermediate stage between the initial and final position of the interface (in our case intrusion is permitted about 1 to 2 miles inland). During the movement of the water table to its final position, the water levels are higher than planned for the final stage. Therefore, there exists an excess flow to the sea throughout the transition period. This is a net loss of water.

The volume of fresh water replaced by salt water as described above, is a one-time-reserve of a considerable volume (Fig. 1) - in Israel's case it amounts to about 12 times the annual natural recharge. The excess flow to the sea throughout the transition period is a loss from the reserve. Storage of the one-time-reserve has to be paid for with water. By pumping far landward the interface movement can be achieved, but most of the reserves will be lost. By pumping nearer to the sea and/or at higher rates, we may save some of it, but the usual pumping will have to be stopped within a few years because of contamination by the salt water movement. However, it is possible to make the interface move at a predetermined required rate. In Israel the reserves were utilized at a rate which facilitated the development of the south. Not only was it the only immediate source of water at a time of heavy immigration, but it enabled the postponement of difficult decisions and the build-up of consumption. When the permanent source of water (the Jordan project) was established it could immediately operate at full capacity due to this build-up of consumption (which required about 15 years).

To further increase the safe yield, and the exploitable portion of the reserves, a method of utilization called "coastal collectors" was developed and applied. The coastal collectors consist of closely-spaced shallow wells along the sea coast. The nearer the "collector" to the sea the more efficient it is. By controlled pumping the shape of the interface can be changed - as shown in Figure 3 without any further significant intrusion. In this manner the necessary flow toward the sea is maintained to check the toe of the interface. After it has fulfilled its "duty", part of the flow is intercepted just before entering the sea. In hydraulic models almost all of the "residual" flow can be intercepted. In reality in the field only about 60% of the residual flow can be intercepted, mainly due to dispersion effects.

By means of the coastal collectors the shape of the interface is changed without affecting its intrusion. The coastal collectors not only increase the safe field, but also instantaneously cuts down the flow to the sea. Thus, it facilitates the recovery of almost all of the available reserves. In model tests 100% of the reserves were recovered when using the coastal collectors as the first step of development.

Having implemented this plan of management, and it has been implemented for quite a few years now, we have practically obtained full control of the water levels (and consequently of the flow in the aquifer). At a distance of 2 to 3

miles from the sea, control is maintained in order to check the toe of the interface. Another control is maintained near the sea by means of the coastal collectors. Consequently, any water recharged to the squifer landward of the control can be fully recovered. There is almost no loss of recharged water (Figure 4).

In Figure 5 the "best" way of utilizing the coastal aquifer, under economic conditions similar to those prevailing in Israel, is illustrated. The first step would be to construct a coastal collector to cut the flow to the sea as soon as possible. Thus the full utilization of the one-time reserves is set up. If no consumers for the pumped water exist initially, the water can be recharged farther inland and kept in storage. Due to the dynamic nature of the underground storage, water can be stored so as to be readily available when and where needed.

The second stage would be to construct more wells and pump farther inland, to move the interface inland at the required rate. The required rate of movement would be dependent mostly on the required rate of utilization of the reserves. The final position should provide the highest feasible safe yield. This program of development is inseparable from the integrated comprehensive master plan. The type of technical solutions and schedules were direct outcomes of the goals set by that integrated plan. To enable the implementation of such a program, one has to start development of the master plan at the earliest possible stage, to avoid other decisions that may block the way.

It should be borne in mind that by cutting the flow to the sea to a minimum, salts will build up in the aquifer due to the consequent decrease in the rate of drainage of salts from the aquifer. In our case, though the build-up is slow, the introduction of desalted water will be needed in time to improve the salt balance in the system.

Losses from aquifers can be kept smaller than those from surface reservoirs. It may also be possible to control the salt balance or to maintain a more favorable distribution of salts in the system, by mixing different kinds of water in the aquifers. Results of special studies conducted in Israel make it possible to control the mixtures by various distributions of pumping both in space and time.

In conclusion, the example just described, illustrates a dynamic solution for water development as a part of a state-wide integrated plan. This solution makes use of existing reserves and allows sea water intrusion in order to obtain higher overall benefits (although some wells may become contaminated).

In general, as development of a region progresses the interdependence of the various resources becomes more apparent. However, the need for integrated planning may exit much before it becomes obvious. This need in Israel was recognized early because of the water shortage and the country's small size. Formulation of a master plan was started together with early exploration. The water law was developed so as to permit highly efficient utilization of the country's water resources.

Today Israel utilizes over 70% of its total water potential, the rest is to be put to use within 5 to 10 years.

We believe, therefore, that our experience may be of help to others, including areas where shortage may not yet be as acute or where management as sophisticated as ours may not yet be needed. I hope our experience will help others.

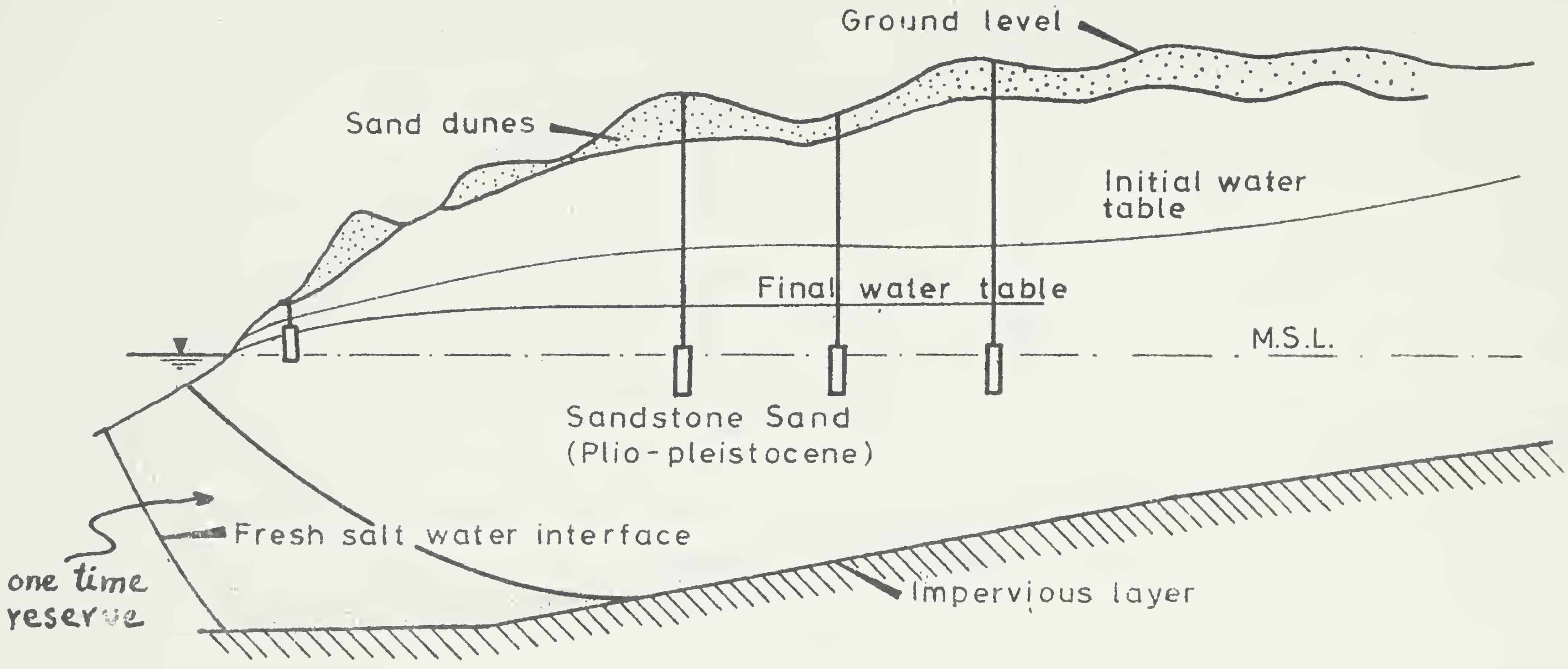

fig. 1:

The coastal plain-Full utilization without coastal collectors

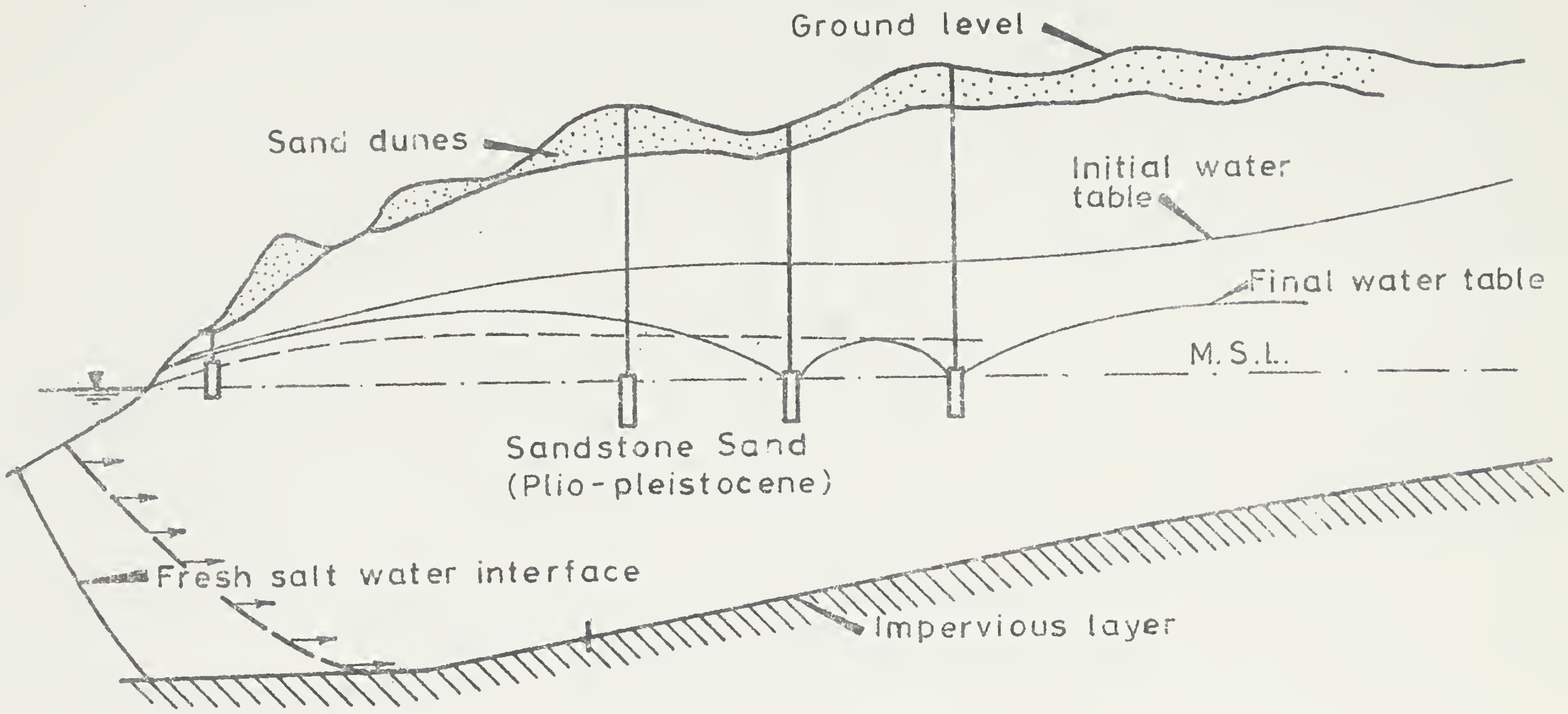

fig. 2:

The coastal plain - Intermediate stage

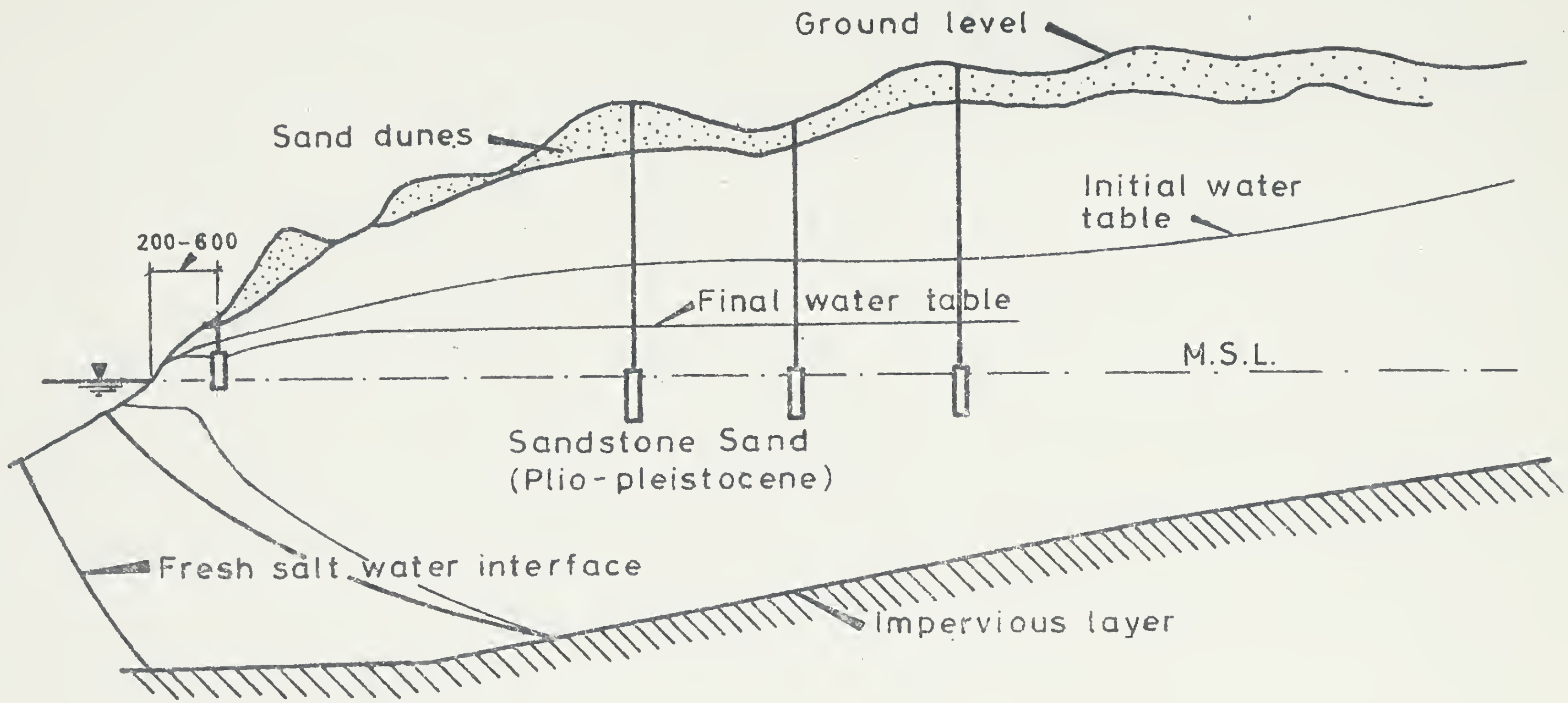

fig.3:
The coastal plain-Full utilization with coastal collectors

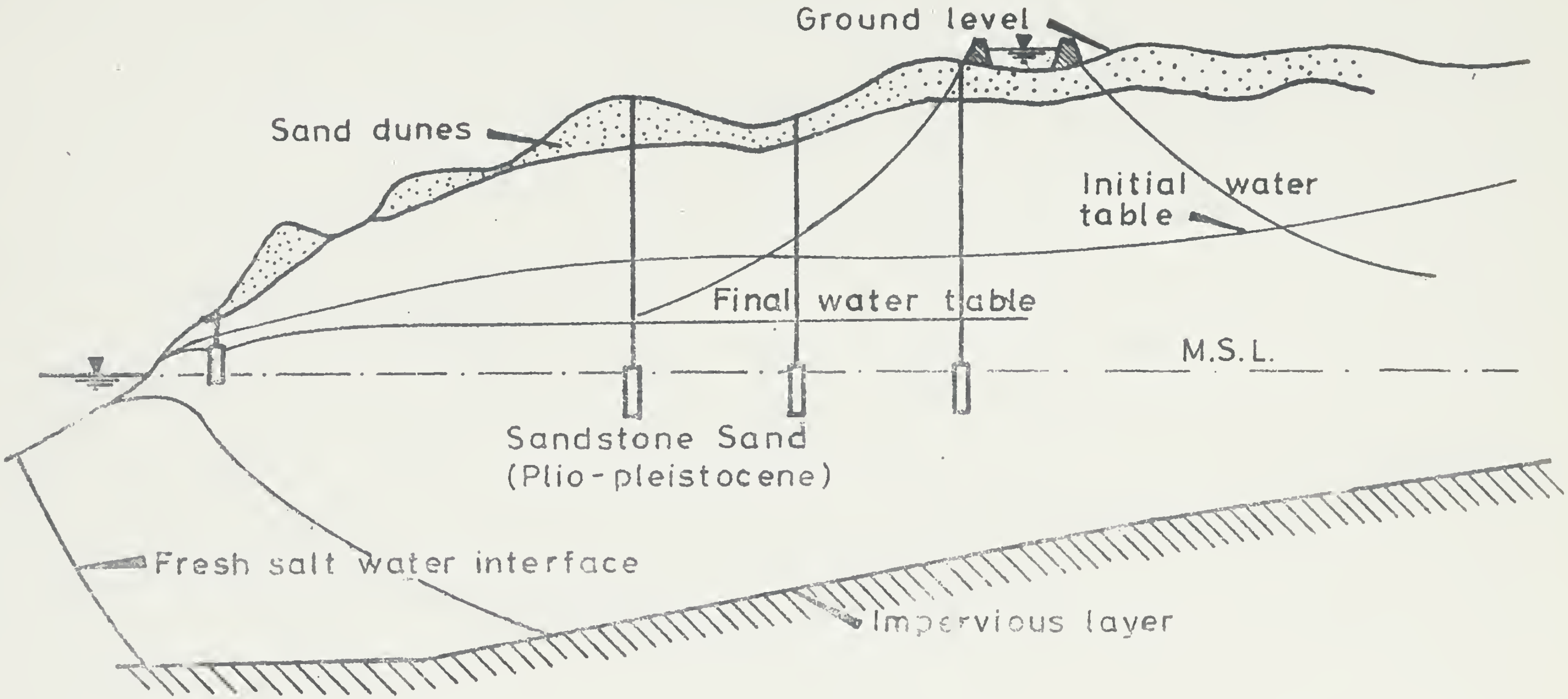

fig.4:
The coastal plain-final stage

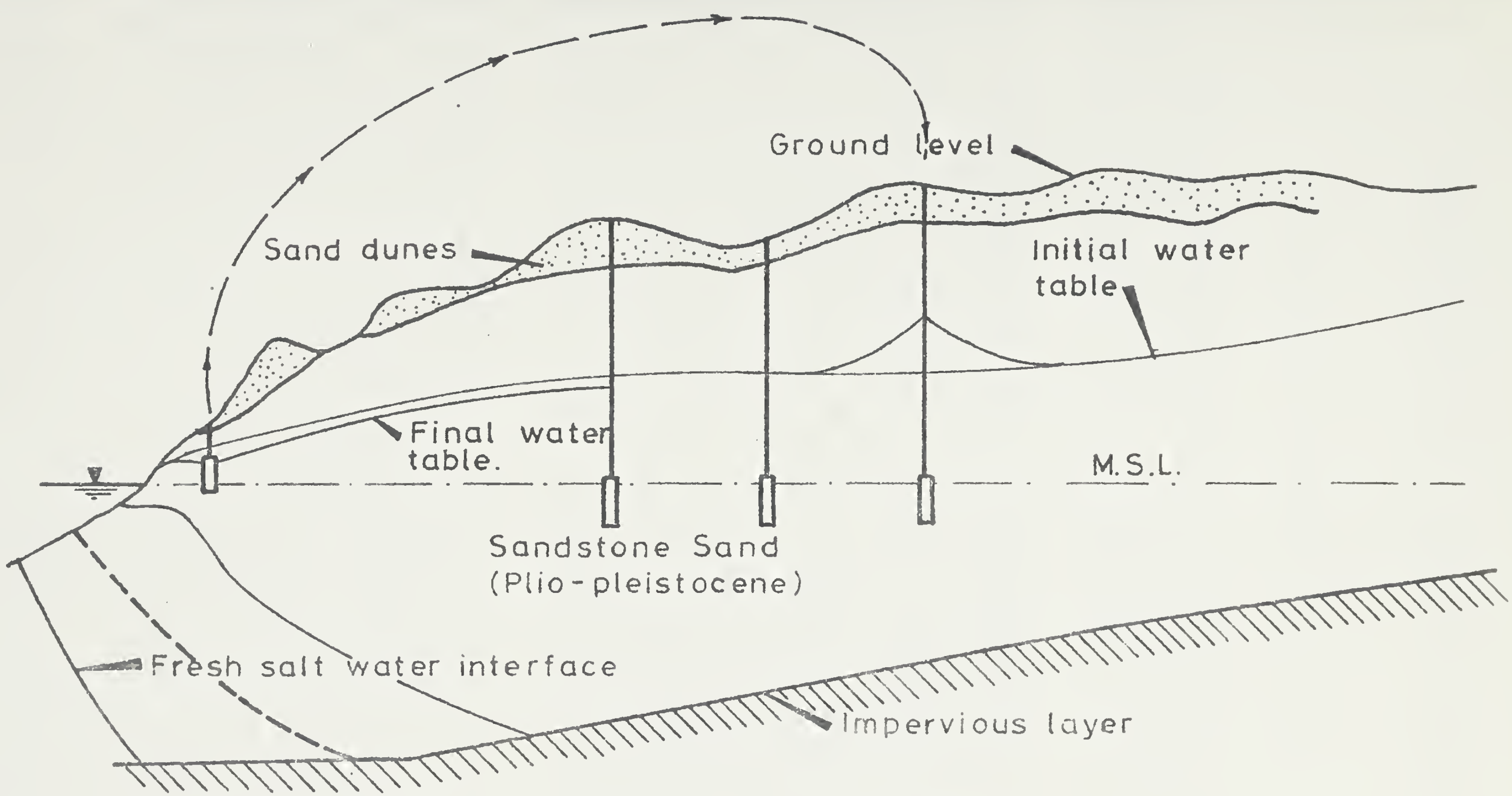

fig. 5:

The coastal plain-Full utilization of reserves

September 1965

H-20

Ground Water Research, University of California, Davis

by

Verne H. Scott

Department of Water Science and Engineering

This paper reports briefly some of the research activities being conducted by staff of the Department of Water Science and Engineering, University of California at Davis. The studies mentioned will illustrate some of the new analytical and experimental techniques being used in research to examine some of the variables that influence the movement, use and development of ground water.

Saturated and Unsaturated Flow in Porous Media. The entry of water into soil and its removal are of prime concern in ground water as well as in both irrigated and nonirrigated agriculture and in watershed management. A number of research studies are underway which are directed towards explaining and predicting the interrelationship of initial soil water content, the transmission characteristics of the soil for water, soil stratification and structure, crop cover, kind and quality of dissolved salts and others. A series of experiments have been conducted using a selected quality of water infiltrating into the soil. Measurements have been made on infiltration into columns of air-dry soil with water flowing horizontally, vertically downward and upward using gamma radiation attenuation equipment. The water movement and soil water profiles were analyzed by a diffusion type equation involving the soil-water diffusivity and soil-water capillarity conductivity. These experiments represent the first attempt to describe capillary rise experiments with a diffusion type analysis and compare them with results for downward infiltration. Additional experiments are being conducted to examine the nature of the parameters when redistribution of water occurs after cessation of infiltration.

Research is underway on the entrance and redistribution of differential pulses of water applied to the surface of the soil. This research has application in ground water recharge, leaching salts, and accounting for the movement of pesticides. Experiments are being conducted in the laboratory at Davis and in the field at the University's West Side and Kearney Field Stations. At the West Side Field Station experiments are underway on the movement and redistribution of salts in an effort to ascertain the nature of the movement of pulses of water in a field soil under particular leaching regimes. These investigations have established that the method of water application significantly modifies the movement of salt through the profile and can result in a saving of one-third the amount of water required to leach salts under standard leaching practices by ponding. The movement and redistribution of chlorinated hydrocarbons (nemagon and dieldrin) are being studied at the Kearney Field Station.

Hysteresis effects are being studied to determine whether the final water content may be influenced by the number or size of pressure steps used in reaching a specific water pressure. Preliminary results lead to the conclusion that the size of the pressure step influences the final water content.

Physical and chemical factors responsible for the transmission characteristics of saturated and unsaturated soils are being studied using a special device which contains the same soil sample and soil solution throughout the period of measurement. Results to date indicate that Darcy's law is not valid for small gradients in a particular soil for the soil solution investigated.

Quality of Recharge Water. The quality of recharged ground water is receiving special attention and has progressed in three steps with the emphasis on conditions prevailing on the west side of the San Joaquin Valley including: (1) Determination of the deep subsoil properties that would affect the quality of percolating waters. This research is based on an analysis of cores obtained from 19 drilling sites ranging from 50 to 500 feet below the ground surface. Interesting results have been obtained which relate depth and location to the concentration of total soluble salts including ionic species, amount of gypsum, lime content, base exchange capacity, exchangeable ions, volume weight, moisture equivalent and pore saturation. (2) Development of a computer program for predicting salt concentrations as variable soil water contents. A computer program has been developed to calculate the theoretical equilibrium of solutes undissociated and solid phase calcium sulfate. $2H_2O$ and exchangeable cations at a given soil moisture content from soil extract data. (3) Application of the computer program to predict the quality of water percolating through stratified substrata. This research involves two steps: (a) the prediction of chemical changes induced by saturating a stratified substrata profile; and (b) prediction of the quality of percolating water and chemical changes in profile distribution. The above techniques and methods have been verified and substantiated by numerous laboratory models. Results of the computer analysis, although an approximation, have been encouraging with extremely good correlation between results of laboratory models and the predictions.

Groundwater recharge through a multiple well system along a coastal aquifer. The objective of this study is to develop general criteria for the optimization of recharge well location and recharge operations to prevent sea water intrusion in coastal regions. To date a computer program has been developed to simulate the effect of a series of recharge wells on a piezometric water profile in a confined aquifer. Although certain limiting assumptions were made, results from the computer analysis were compared with data of piezometric buildup due to recharge performed by the Orange County Water District in the Santa Ana Gap Region in Orange County and a favorable comparison was obtained. Differences between the computed and field measurements of the piezometric water surface occurred but are accounted for when correlated with seasonal irrigation and municipal pumping practices and other recharge sources not related to the water district's well recharge project.

The potential for groundwater recharge by a trench or down wells. A study has been made on the merits of a long, continuous trench or recharge pit versus down wells at some optimum spacing for a situation where a relatively impermeable material occurs at the surface and a permeable rechargeable aquifer is at a relatively shallow depth. Consideration was given to a trench excavated as a long pit of a designed width and length and backfilled with a filter gravel, and down wells constructed of a large diameter hole down to the shallow dewatered aquifer backfilled with graded gravel and supplied with water by a simple distribution system or flow in a natural channel.

Analysis of these two systems was made for the groundwater situation in and around the City of Stockton where a serious decline in the water level has taken place. The two alternate schemes were compared on the basis of recharge potential and cost using computations of total recharge by steady and nonsteady flow analysis. Results were obtained on the effect of well spacing on individual wells and on total recharge volume, recharge cost per acre-foot, and expected annual cost per mile for the trench and well system operating on three periods of water availability per season. In general, the trench system was favorable in all respects.

Effect of well interference on discharge and drawdown of individual wells. In this study the combined effects of well interference and variation in discharge in a confined aquifer was made. In one phase of the study the well discharge was assumed to have a definite relationship with time and in the second phase the discharge was considered independent with drawdown following a discharge-drawdown curve supplied by the pump manufacturer. A general equation for drawdown at any point within a group of pumping wells was developed. An IBM 7040 computer was used to determine successively the drawdown and discharge at each of the wells in the groups. The analysis included consideration of well spacing on 1,000, 3,000, 5,000 and 10,000 foot intervals. Tentative conclusions reached were: (1) well interference problems are more pronounced in aquifers of low coefficient transmissibility and low storage coefficient; (2) in areas where mutual interference of wells was pronounced decline and discharge for a well operating in a given array is significant thus making the constant discharge concept invalid; and (3) decline and discharge for wells operating in finite radial aquifers is more pronounced than for identical wells operating in infinite aquifers.

Water and salt balances in a two-aquifer system. A preliminary study is under way to investigate the effects of conjunctive use of groundwater and imported surface water on the hydrologic and salt balances in a system comprising an unconfined aquifer separated from an underlying confined aquifer by a relatively impervious layer. Based on such a scheme, it is desired to predict groundwater levels and piezometric heights as well as the salt concentration of the water given a prescribed operational regime. A set of four differential equations governing the system has been derived and numerical analysis of the system indicates possible solution by use of the digital computer.

Optimum schedule for cyclic operation of wells. In the operation of wells for water supply, pumps are seldom operated continuously. Intermittent pumping and recovery schedules are practical and quite common operational practice. Study is under way to develop a schedule which would maintain the drawdown in a well within certain specified range. The residual drawdown, after each full cycle of pumping and recovery, has been used as a criterion for planning of an optimum schedule under which a residual drawdown is maintained at a constant level. If a program schedule of operation can be worked out for mutually interfering wells, it would have application to problems of drainage of shallow water tables in agricultural lands.

Robert A. Skinner

The topics assigned to me were a summarization of salient points of the economics and acceptability of ground water recharge, and an opinion regarding recharge in long range planning.

The following remarks apply in general to the Southern California coastal plain drainage area, a region endowed with truly munificent ground water resources which have been a primary factor in nurturing an unprecedented economy. More specifically, the discussion relates to the coastal basins in the counties of Los Angeles and Orange, where the Metropolitan Water District of Southern California has taken a conspicuous part in a sustained ground water recharge program by supplying imported water for this purpose at approximately the out-of-pocket cost of pumping and transporting the water in its Colorado River Aqueduct system.

To digress slightly, we might view the ground water management problem as one segment of the still broader challenge: Are people losing the contest with self-generated influences which operate to degrade their environment in areas of highly intensive economic development, such as the Southern California coastal plain?

Let us examine the question not merely of acceptability but of necessity for preserving the usefulness of the ground water basins.

The acute need for not only continuing but accentuating an organized program of ground water conservation and recharge, and its acceptability in the economics of continued development in Southern California, can be expressed in simple terms. There is no tolerable alternative. In the absence of such a conservation program, there would be continued encroachment of saline water at an accelerated rate into the aquifers in the near coastal areas, and progressive exhaustion of the more important sub-basins farther inland which lie at sufficiently high elevations to be inaccessible to, or are protected geologically against, the encroachment of sea water. The present mechanism of consumer water service in which an aggregate of hundreds of cities, public water districts, investor-owned water companies, and mutual water companies supply their service areas in whole or in part by water derived from wells, would have to be extended and remodeled to enable connections to be made directly to available import facilities. Dependability of service from direct connections to aqueduct systems would require vast multiplication of surface reservoirs for which the availability of suitable sites already is approaching the vanishing point in highly populated areas. Definitive evaluations are not available for disclosure of comparative costs of a replenishment program adequate to preserve the ground

water basins for continued utilization, on the one hand, and conversion of the multiplicity of water systems so as to afford direct connections to water import facilities, on the other hand. However, such comparative costs even if known precisely would not be decisive. There are more crucial factors in the strategic and economic necessity for preserving the ground water resources. One is the emergency value of optimizing ground water resources and extraction facilities for utilization in times of possible outage of long aqueducts. Another is a localized means of providing for summer peaking which otherwise would require substantial amplification of both import and surface distribution facilities. There is also the value of underground storage in the regulation of imported supplies, affording exceptional advantages not obtainable by surface storage.

Human activity has resulted in influences both adverse to percolation of storm runoff from the coastal plain watersheds, and favorable to conservation. A significant example of adverse influences is observed in the case of the Ballona Creek watershed, embracing a total of about 130 square miles including a considerable portion of the south flank of the Santa Monica Mountains and adjacent valley land. In the February 1914 storm, one of major proportions in the recent history of the coastal plain drainage area, and which produced the highest one-hour intensity of record at the Los Angeles rain gage, the peak runoff into the ocean from Ballona Creek was estimated at roughly 6,500 cubic feet per second. Under present conditions, with storm drains and paved roads extending into the canyons and across the valleys and with much of the habitable surface area rendered relatively impermeable by man-made structures, a flow of greater magnitude is produced by comparatively minor precipitation. In addition to impairment of opportunities for percolation, urbanization presents a hazard to ground water quality by refuse disposal in land fills where percolating water could be exposed to contamination, particularly where such disposal is permitted in highly permeable areas, as in gravel pits. Lowering of the water table in many valley areas has resulted in substantial subsidence which, in addition to other detrimental effects, is accompanied by a loss in storage capacity in the affected aquifers. On the favorable side, the construction of flood control reservoirs in catchments tributary to the coastal plain has afforded valuable, if limited, means for temporary impoundment of flood water and its later release under controlled conditions into spreading areas. Such areas include both river channel lands and off-channel sites acquired and operated for replenishment purposes. Moreover, truly remarkable progress has been made in Los Angeles and Orange Counties in the application of imported water for replenishment of ground water basins.

Beginning in August 1949, delivery of Colorado River water for percolation in the bed of the Santa Ana River was begun under the auspices of the Orange County Water District (OCWD), a special district with boundaries encompassing most of the coastal basin in Orange County. In 1961 deliveries were commenced additionally to

an excavated pit in an off-channel location near the mouth of Santa Ana Canyon, the overflow from which can be conducted into Carbon Creek flood control channel, along which are additional percolation basins. To June 30, 1965, a total of 1,529,000 acre-feet of Colorado River water has been delivered by the Metropolitan Water District for ground water replenishment in Orange County.

In the initial operations, the deliveries were accomplished through contracts with OCWD and Orange County Flood Control District. Subsequent to annexation of Orange County Municipal Water District to Metropolitan in 1951, deliveries have been made under the auspices of the Municipal Water District with OCWD managing the replenishment operations. In 1953, the OCWD Act was amended to provide for the levy and collection of a replenishment assessment against all persons producing ground water within the area of that District. The first replenishment assessment was levied by OCWD in 1954 at the rate of $3.50 per acre-foot on all ground water produced. This rate has been increased progressively and is currently $8.00 per acre-foot. In 1961, the OCWD Act was further amended to authorize collection of an additional replenishment assessment on all ground water produced for purposes other than the irrigation of commercial crops. This additional assessment is currently $3.00 per acre-foot. Furthermore, an ad valorem tax rate is levied in OCWD, currently 20 cents per $100, and a portion of the proceeds is used for purchase of imported water to make up accumulated overdraft.

Results of the recharge program in Orange County are striking. In the face of a population increase from one-third of a million to more than a million in Orange County during the past decade, and in spite of a severe drouth during the past 20 years in the Southern California coastal plain drainage area, with an accumulated deficiency in that period equivalent to 4 years of normal precipitation, and also of increasing extractions in the Upper Santa Ana River area (which OCWD contends are substantially in excess of rightful use and has sought by extended litigation to restrict), there has been achieved a remarkable recovery of ground water levels in the Orange County coastal basin. In this connection it must not be overlooked that wholehearted collaboration by the Orange County Flood Control District has been an indispensable ingredient in the success of the recharge operation.

The profile of ground water surface from the mouth of the Santa Ana Canyon to the ocean at Huntington Beach, taken as an average along lines extending perpendicularly from the profile plane both ways to the boundaries of the basin, was higher at November 1, 1964, than at any time since year 1948, and upstream from Santa Ana was higher than at any time since 1944. Just downstream from the City of Olive, there was a recovery from 10 feet below sea level in 1959 to 90 feet above sea level in 1964.

The volume of ground water in storage in the OCWD area on November 1, 1964, is estimated to have been about 85,000 acre-feet

greater than on November 1, 1944. This does not mean that sea water intrusion into the basin has been arrested, but the rate of inflow has been reduced. Some thousands of acres of OCWD area are still underlain by salt water and its movement inland is continuing. Thus, it is obvious that it would be highly injurious to discontinue or even substantially diminish the recharge program.

OCWD proposes to purchase 175,000 acre-feet of Colorado River water for ground water replenishment during the 1965-66 season, or 25,000 acre-feet more than the estimated excess of extractions above replenishment from local natural sources during 1964-65.

The conservation and recharge accomplishments in Los Angeles County have been no less commendable, although industrial and other urban encroachment on permeable forebay areas and control of floods by means of concrete-lined channels have proceeded to a far greater extent than in Orange County.

Deliveries by Metropolitan to West Basin Municipal Water District for injection in the West Coast Barrier began in 1953, and deliveries for spreading in the San Gabriel River channel and off-channel basins in the Montebello Forebay began in 1954. In the latter case, the operation was begun by means of releases from Metropolitan's system into Puddingstone Reservoir and thence by way of Walnut Creek to the San Gabriel River. Initially, water for replenishment in the Central Coastal Basin was sold under contract directly to the Los Angeles County Flood Control District. Administration of deliveries for spreading in the Montebello Forebay was taken over in 1959 by Central Basin Municipal Water District. The Central and West Basin Water Replenishment District began operations in 1960 with an initial tax of $3.19 per acre-foot of water extracted from wells within the Replenishment District. This tax has increased to $7.31 per acre-foot at the present time. At present, Metropolitan sells water to Central Basin Municipal Water District for resale to both the Flood Control District and the Replenishment District for recharge by spreading in the Montebello Forebay and by injection in the Los Alamitos Barrier, and to West Basin Municipal Water District for resale to the Replenishment District for injection in the West Coast Barrier. In addition, Upper San Gabriel Valley Municipal Water District in 1965 began an annual program for purchase of water from Metropolitan for replenishment in the Upper San Gabriel Basin by means of releases into the San Gabriel River channel. All barrier facilities and transport pipelines for delivery thereto from Metropolitan's system have been constructed and are operated by the Flood Control District.

To June 30, 1965, a total of 1,087,500 acre-feet of Colorado River water has been delivered for spreading in the Montebello Forebay, 10,000 acre-feet in the Upper San Gabriel Basin, 71,700 acre-feet for injection in the West Coast Barrier, and 1,600 acre-feet for injection in the Los Alamitos Barrier. This adds up to a

grand total of 1,170,800 acre-feet of Colorado River water applied for ground water replenishment in Los Angeles County since beginning deliveries for this purpose in 1953.

The ground water pressure levels presently are below sea level in practically all of the area of the Central and West Basin Water Replenishment District, except in the Central Basin non-pressure area which lies generally between the hills on both sides of the Whittier Narrows and an arc concave to the northeast and passing half way between Bellflower and Downey. In three of the troughs or sinks the piezometric elevation is from 70 to 90 feet below sea level. It does not appear feasible to recreate a ground water hydraulic gradient from inland continuously toward the coastline in the foreseeable future, nor would it necessarily be economically justifiable to do so. Under these conditions, the main reliance against continued intrusion of sea water into the aquifers will be the barriers created by injecting fresh water in lines of wells inshore from the coast. The 11-mile long West Coast Barrier is expected to be completed in 1966. The Los Alamitos Barrier, which straddles the boundary between Los Angeles and Orange Counties, is being constructed jointly by the flood control districts of the two counties and is expected to be completed by about 1963. The proposed Dominguez Barrier, inland from the Los Angeles Harbor, is not yet under construction. In spite of increasing urban development and the long continued drouth conditions referred to previously, the replenishment program has brought about a moderate recovery in portions of the Central and West coastal basins. The landward movement of sea water will not be fully arrested until the three barriers have been completed and are in full operation.

Of critical importance in connection with the preservation of the coastal ground water basins in Los Angeles and Orange Counties will be the quantities of imported water available for replenishment during the period prior to availability in Southern California of State project water. Unless the rainfall in the Southern California coastal plain drainage area increases substantially above that experienced in recent years, the excess of extractions over total replenishment in the coastal basins could reach a total on the order of a million and a half acre-feet during the period prior to scheduled delivery of State project water in 1971. On the other hand, if rainfall is substantially above average during this period, there may be a continuation of the trend of recovery of ground water levels experienced since replenishment with Colorado River water was started.

In recent years there has been a great deal of deliberation among the water supply fraternity and in the Legislature, in regard to ways and means for optimizing ground water basin management. The remarkable results in Los Angeles and Orange Counties alluded to above were achieved by locally instituted water associations and by special districts organized under the applicable statutes and financed through taxation and water extraction charges levied within their respective boundaries.

In this connection it should be recognized that the State Water Project will provide an unique opportunity for significant accomplishment in basin management. In the interval between the start of delivery of State project water in Southern California and the full utilization of the supply available from the project, expected to occur about year 1990, there might be a total in excess of the aggregate of annual entitlements (scheduled deliveries) of as much as 16 million acre-feet that could be obtained by the Southern California water contractors on an incremental cost basis. For a substantial portion of such excess water the incremental unit cost would approximate $20 per acre-foot, representing the cost of pumping and other operation and maintenance costs that vary according to the quantity of water being transported in the aqueduct, and costs attributable to the earlier installation of pumping units and other staged features.

Availability of such excess State project water will afford an interim opportunity for effectively reversing the adverse trends of the past half-century in the exploitation of ground water basins. This same kind of opportunity, on a lesser scale, was presented in the early operation of the Colorado River Aqueduct but in that period, extending from 1941 to about 1955, organized jurisdictions and facilities necessary to take advantage of the available supply had not sufficiently materialized. Now the scene has changed; jurisdictions and operational mechanisms have been created and tested which could accomplish such replacement of overdrawn underground storage in the Southern California coastal plain basins as may be found economically justifiable, utilizing excess water available from the State Water Project.

Omitted from the foregoing discussion has been any reference to the extended litigation in the Raymond Basin, West Basin, Central Basin, Upper San Gabriel Basin, and Lower and Upper Santa Ana River Basins, among many others. Water rights in the Raymond and West Basins have been fully adjudicated, adjudication is pending in the Central Basin, and a negotiated agreement has been reached between the Central Basin and the Upper San Gabriel Basin interests. Orange County Water District, after having obtained a favorable verdict in an action against four cities in the Upper Santa Ana River area, has instituted suit to adjudicate the entire Santa Ana River Basin. Such litigation, while of painfully extended duration and burdensome expense, appears in the end to reach essentially logical and equitable determinations, administered under continued court jurisdiction and with water masters supplied by the State Department of Water Resources or other selected agency through a court reference procedure. Observation of evidence from past history indicates that continuing jurisdiction of the local water and flood control agencies in the basin management field, augmented as necessary by the adjudication and court reference procedures available under existing law, should be adequate to bring about restoration of the basins to such conditions of ground water storage as the controlling jurisdictions might deem most appropriate, subject of

course to availability of adequate supplies of imported water. As pointed out above, such availability in Southern California cannot be expected prior to beginning of delivery of State project water.

In the deliberations referred to above, another general type of jurisdiction has been envisaged. Under this concept, there would be created by law an agency of somewhat unprecedented jurisdiction, endowed with power to take steps deemed necessary for basin management. The powers of the special agency would enable it to initiate and facilitate adjudication of water rights; control the location and quantity of extractions; direct the construction and expansion of water transport and distribution facilities under whatever ownership might be involved; acquire and operate ground water recharge areas; utilize underground storage space; control discharges of water that might degrade the quality of ground water; construct, operate, and maintain ground water barriers; and levy property taxes and water extraction taxes for financing all of the foregoing. Presumably the supposition of the proponents of such a centralized management concept is that the specially endowed agency would achieve results superior to those obtainable under the interplay of separate local agency control combined with adjudication and court reference procedures under existing law. We might draw an analogy here between a centrally managed economy and the economic interplay of the market place. In any event, traditional concepts of property rights and jurisdictional prerogatives of presently constituted public utilities and local governmental agencies would have to be modified substantially before a superentity vested with the broad powers enumerated could be created.

* * *

Ernest M. Weber

It is a privilege to be invited here today and to have the opportunity to participate in this conference. I would like to present a brief discussion on ground water basin management. Such management entails consideration of engineering and economics as well as the solution of organizational and legal problems. Each of these is worthy of a lengthy discussion in itself; however, because of other panels, I shall concentrate on a brief consideration of some of the engineering aspects based on ground water basin management studies currently underway in the California Department of Water Resources.

The present total use of water in California is about 25 million acre-feet per year, and this water is furnished about equally from surface and ground water sources. The 12 to 13 million acre-feet of water extracted annually from the ground water basin exceeds by about three million acre-feet the average annual replenishment to the basins. Despite the resulting overdraft conditions, it is apparent that these ground water basins will be used in the future so long as their use continues to support the economic development of California.

The existing level of economic development, in large measure, can be attributed to the availability and utilization of these underground water resources. Studies indicate that there is a vast amount of underground storage space in the area, and that a large portion of this space is filled with ground water today. This ground water in storage, as well as the underground storage space itself, provides a means of conserving runoff from erratic precipitation and flood waters and for storing and releasing such water in controlled patterns so that water may be available for use on a more uniform basis during wet and dry periods alike. These basins also provide a natural underground water distribution system.

In our planning studies, we find that the full utilization of these extensive ground water basins in coordination with surface facilities will be necessary to provide for all future water requirements of California.

Each of our planned utilization investigations is divided into three consecutive phases to obtain the desired physical and economic information. The first phase is a comprehensive geologic study and the second, a detailed hydrologic study. These two phases culminate in development, testing and verification of ground water basin model which is used in the third phase. The third phase is an operational-economic study which leads to selected plans for basin management.

In the last portion of the third phase, after a wide range of physical and economic information has been assembled, related organizational and legal problems of each plan are identified and analyzed.

All of the techniques developed in our planned utilization studies are of a general nature and suitable for use in any ground water basin.

In order to manage the basin effectively, it is important to know where the water is and to be able to forecast how fast, and in what direction, this water will move under various plans of basin operation.

Observation of the behavior of ground water under these varying conditions is possible only through the use of a model which can simulate a wide range of known and projected conditions. Since the construction and operation of a scale hydraulic model of each basin is impractical for reasons of both time and money, a procedure for developing, testing, and verifying a mathematical model of the ground water basin through the use of computers was conceived. Today, I will concentrate on the development and testing of the mathematical model. In order to achieve a reliable mathematical model, detailed knowledge of the hydraulic and hydrologic characteristics of the basin are needed.

Therefore, a comprehensive geologic study was made which gave us the size and shape as well as the storage and transmission characteristics of the ground water basin. This information is used in the development of the model. Detailed hydrologic studies were conducted to determine the historical water supply, use and disposal for testing and verifying of the model. The analysis of the historical hydrologic events climaxes in the development of reliable estimates of future water supply and water' demand for the basin.

In formulating, testing, and verifying the model, each of the complex elements of the prototype making up the ground water basin, and its water supply, use, and disposal are analyzed and simplified so that they can be used in the model. Successful simplification of the complex prototype calls for full utilization, interaction and cooperation of men in the technical fields related to geology, hydrology, hydraulics, mathematics, and electronics.

To determine the proper values of the various coefficients, for the model, data from the detailed geologic study are reduced to our first, "best value" of transmissibility and storage. Data from the comprehensive hydrologic phase gave our annual historic water levels and time dependent net replenishment for an 11-year study period. Supported with the initial best values, of the coefficients, the actual computer application is undertaken. Both general purpose analog and digital computers have been used, for model development and testing.

The testing and verification process consists of impressing the net historic time dependent replenishment or extraction dates on the model and graphically recording the resulting water level responses. The original estimates of the values of parameters are adjusted, systematically, within the reasonable limits of data, by the team of engineers and geologists who developed the data. This cut-and-try

method, is continued until the desired match between computed and field measured water levels is obtained, thus verifying the models reliability. It is during this cut-and-try period, in which the results of the changes can be immediately observed, that the engineer gains a keen insight into the behavior of the basin.

In the planned utilization studies the maximum delivery capacity of the primary surface distribution system within a study area is an important factor in the economic analysis of conjunctive operation of surface and subsurface water systems. Utilizing the computer, a mathematic model of a pipeline network was developed to simulate the hydraulic characteristics of an expanding pipeline system. From these models the maximum delivery capacities can be determined.

Once the mathematical models of the ground water system and pipeline system have been developed and verified for reliability, they are used to analyze various plans of basin operation. The results of these separate analyses are combined in a coordinated operation, from which the specific surface and subsurface facilities needed to execute each alternative plan are determined. Included are the costs of construction, operation and maintenance of such facilities, and the cost of imported and pumped water. By making a comparison of the costs of all practical plans it is possible to select the plan which is most economical.

General purpose analog and digital computers have been selectively used as tools to arrive at a plan to provide water service most economically. In using these computers, the functions best performed by these computers were combined with those best performed by human thought. The use of such tools has lightened the tasks that were once the sole province of the human brain. Tedious computations, digestion of huge amounts of data, and solving of complex equations -- all of these tasks and more, were assigned to the computers. Thus, these computers freed the mind of the engineer, enabling him to probe deeper into problems of greater complexity and scope.

GROUND WATER RESOURCES USING NUCLEAR TECHNIQUES

Harlan H. Zodtner

Lawrence Radiation Laboratory, University of California
Livermore, California

October 15, 1965

The Plowshare Program was established by the Atomic Energy Commission in June of 1957 for the purpose of developing commercial uses of nuclear explosives. The Atomic Energy Commission gave Lawrence Radiation Laboratory the responsibility for feasibility studies and the technical direction of the program.

One area of interest and promise to Plowshare is the field of water resources development. Nuclear explosives have given us a new tool of tremendous force and energy. Never before in the history of mankind has there been so much energy which could be packaged into so small a unit at such a low cost per unit of energy. This new tool should not be considered competitive to conventional methods, but rather an additional tool which will enable engineers to accomplish certain projects on an economic basis which now may not be feasible economically. In the matter of excavation, for example, as a rule-of-thumb, the moving of 1 million cubic yards of material and/or removal of 100 feet of overburden is minimal in achieving economic use of nuclear explosives. Size is important.

In California and the southwestern United States artificial recharge of ground water is being practiced on an increasing scale. The rapid population growth, together with water deficiencies in this area, will require additional study and a new technology. In establishing an efficient artificial recharge project, it is desirable to maximize the infiltration rate, wetted area, and continuous water contact with the ground surface. Large craters, properly constructed by nuclear explosives and properly placed, could achieve these conditions. From many cratering experiments conducted under the auspices of the Atomic Energy Commission at the Nevada Test Site much has been learned about crater formation using nuclear explosives, and this technology, properly developed, could materially aid in some projects of ground water recharge.

When a nuclear explosive is detonated underground at an appropriate depth, a crater is formed at the ground surface by the coupling of part of the explosive energy into ejected material. The size and shape of an ejecta crater depends upon the depth of burial of the explosive, the yield, and the media. Explosions at great depth in competent rock produce cavities which are contained entirely below ground surface. Similar explosions in unconsolidated material form subsidence craters.

Figure 1 shows a profile of a nuclear crater. The apparent crater is defined as the one visible on the ground surface, the dimensions being measured with respect to the original ground surface. The true crater lies below the apparent crater and is filled by fallback material up to the apparent crater

boundary. The rupture zone immediately surrounding the true crater consists of large amounts of fractured and crushed material and is caused by shear failure and gross displacements resulting from faulting and underthrusting. Beyond the rupture zone and merging into it lies the plastic zone, where small uniform permanent displacements have occurred. At the outer limit of the plastic zone displacements decrease to infinitesimal values; there the elastic zone begins. The dimensions of the various peripheral zones vary with the type of media.

We have the technology to form craters by ejection of material, to create craters by subsidence, and to create contained cavities in competent rock. The SEDAN event illustrates an experiment performed at the Nevada Test Site in the continuing study of crater phenomenology.

SEDAN was detonated at 10 a.m. July 6, 1962. The base surge formed and continued to grow until it covered an area about 5 miles in diameter. The main cloud rose to a height of 12,000 feet above the desert floor. The dome rose to a height of 290 feet before it vented at 3 seconds. A very large fraction of the radioactivity that escaped from SEDAN was mixed with the fallback in the crater area. Thus, the cloud carried only a small fraction of the radioactivity. The crater was about 1,200 feet in diameter and 320 feet deep. The lip ranged in height from 20 to 100 feet. The engineering predictions and the results compare favorably.

Using the SEDAN crater dimensions as a reference point, let us examine ground water recharge applications.

A nuclear crater located in permeable alluvial material and supplied with water which is permitted to infiltrate into the ground would serve as an excellent structure for artificial recharge of ground water. It could be compared to a combination of the conventional basin and pit projects, having the large contact area of a basin and the depth and storage characteristics of a pit. In terms of size and volume of water which could be handled, a nuclear crater would exceed any present conventional individual project.

In forming a crater it is expected that the postshot permeabilities in the formation surrounding the apparent crater are at least as large as preshot, especially on the steep slopes of the crater where the water would principally infiltrate. This is the model situation, but in practice, infiltration rates would depend on soil and substrata and whether or not the flow between the crater and water table were saturated. In certain formations, evidence suggests that the permeability decreases below the central portion of the apparent crater. In alluvial material with shallow impermeable lenses, the crater ruptures and removes these lenses, and thereby furnishes a hydraulic path to the more permeable strata.

If water is maintained in a crater, a ground water mound such as that shown in Fig. 2 would be superimposed on the water table by downward percolation from the crater. Water will move vertically downward from such a recharge pit until it encounters the water table or a substratum that will perch water. The mound will rise and will assume a size and shape, depending upon the recharge, permeability of soil and gradients. The case shown here is for an equilibrium between the rate of recharge and lateral dissipation of the mound.

From observations reported by Suter & Harmeson[1] on small recharge pits, maximum infiltration rates occur on the sides, while any silt in the water tends to collect on the bottom. Other factors on which this depends include flow rates, the slope of the sides, and the size of particles. Clay colloids will collect along the sides, and this will be particularly true when most of the flow is through the sides. Total infiltration rates vary with time and water depth, temperature, and quality. Assume for illustration, an average recharge rate of 1 foot of water per day. In a 25-acre crater having a storage volume of 2,900 acre-feet, 9,125 acre-feet of water could be recharged annually. The 25-acre crater size has been used, since it relates to the SEDAN event.

There is a relationship between the yield of a nuclear device and the volume of the crater. Figure 3 shows this, and also the relation between yield and crater depth and radius for optimum depth of burial.

Before this new construction technique will gain acceptance, its economic feasibility must be clearly demonstrated. During 1964 the Atomic Energy Commission released revised charges for two nuclear devices. These charges are $350,000 for a10-kt device and $600,000 for a 2000-kt (2-megaton) device. Charges for intermediate yields may be approximated. These charges cover nuclear materials, fabrication and assembly, together with arming and firing services. Not covered are costs of safety studies, site preparation and support. The Atomic Energy Commission's statement pointed out that at the present time the Commission is not authorized to supply nuclear explosives on a commercial basis, although the Commission may engage in research and development arrangements, including demonstrations of a particular peaceful application for nuclear explosives.

Using the cost figures referred to above, Professor David Todd,[2] working under contract to the AEC, made comparative cost estimates for artificial recharge projects constructed by conventional methods and by nuclear explosives. He found that an economic advantage for nuclear construction can be anticipated for volumes exceeding 6,000 acre-feet.

Figure 4 gives the relationship between volume (in acre-feet), crater area (in acres), and nuclear yield (in kilotons). To achieve a crater of 6,000 acre-feet, a 150-kt device would be required.

Professor Todd's document titled "Nuclear Craters for Ground Water Recharge"[3] contains the following conclusion:

> "The technical and economic feasibility of constructing nuclear craters for artificial recharge of ground water can be demonstrated for many situations. Further study of this important new construction tool appears to be warranted with a view to construction of demonstration projects for the benefit of agencies responsible for water resources management."

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[1] Illinois State Water Survey Bull. #48.

[2] Todd, David, Journal American Water Works Association, Vol. 57, No. 4, April 1965.

[3] University of California Lawrence Radiation Laboratory, UCRL-12060.

The creation of craters having storage volumes of 12,000 acre-feet are technically possible. Feasibility studies indicate that craters of 2,000 acre-feet are economically practical in certain situations of land costs and water values.

One of the significant advantages of craters for water storage is their flexibility of location, since the exacting topographic and geologic conditions required for a conventional dam and reservoir do not apply. Construction of a storage reservoir is possible in open level country. Craters of size mentioned would make excellent temporary or terminal storage facilities for regulation of local water supply needs. For imported water, irrigation districts could meet seasonal needs and municipalities could meet peaking requirements.

In water resources applications, one problem of major interest concerns the radioactive contamination of water in or near the crater. If the crater is sealed or if water infiltrates, no contamination of water within the crater itself can take place. Radioisotopes such as cesium and strontium, which have important biological implications, travel only short distances with underground water before being exchanged and bound to fine-grained particles in the surrounding rock formations. Tritium, which moves freely with ground water, may pose a definite problem. However, tritiated water coming from the fallback zone could, if necessary, be displaced and pumped out by peripheral wells within a few months. This water can be beneficially used to irrigate certain crops. In the throwout zone, tritium can be removed by evapotranspiration or by isolating the zone from percolating water.

The ground shock produced by a nuclear explosion generates seismic waves which travel many miles, with intensities which are potentially damaging to structures and other cultural features. The mechanics by which this energy travels is understood well enough so that predictions of peak particle velocities at various distances can be made if the geology is known. At a peak particle velocity of 8 cm/sec there appear to be less than 1 percent probability of vibrational damage to residential structures, such as cracking of plaster. Recent experience with the SALMON event indicates that seismic energy from a nuclear explosion can cause settlement which results in structural damage usually associated with foundation settling.

Air blast problems can result from direct blast or from ducting. The distance at which direct blast waves produce a given peak overpressure scales as the cube root ($W^{1/3}$) power of the explosive yield, and is fairly independent of wind and weather out to a range of about 5 miles. Beyond that distance, refraction or ducting effects predominate. Experience has shown that there is a 50 percent probability of damage to average sized windows if the peak overpressure is 4-1/2 millibars, and to average wood doors at 13 millibars. A safety criterion of 2 millibars is used to assure safety.

The question is often asked, "What becomes of the material which is ejected from the crater?" Practically all of the large rock missiles will be carried to an area around the crater equal to one crater diameter.

The Atomic Energy Commission has stated they will continue to work with other groups in studying the contribution their proposals for projects could make to the research and development program. It is expected that technical and economic information can be derived from such projects to help develop and

demonstrate peaceful uses for nuclear explosives. In such projects it can be expected that the Commission will negotiate the charge to be made for the nuclear explosives and related services based upon a number of factors, including the nature of the contribution by the other party, the economic value of the project to the other party, and the value of information to be received by the Commission.

Work performed under the auspices of the U. S. Atomic Energy Commission.

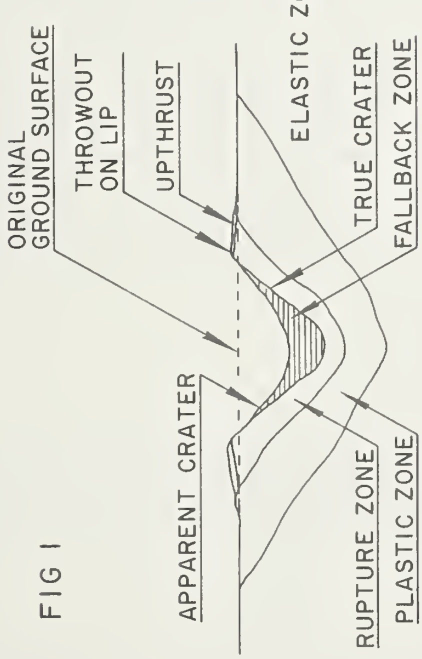

FIG 1

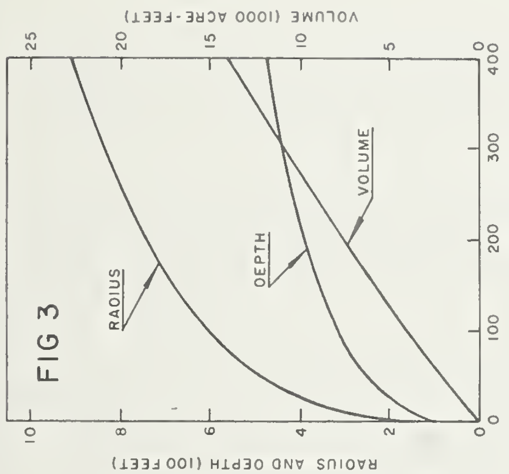

FIG 3

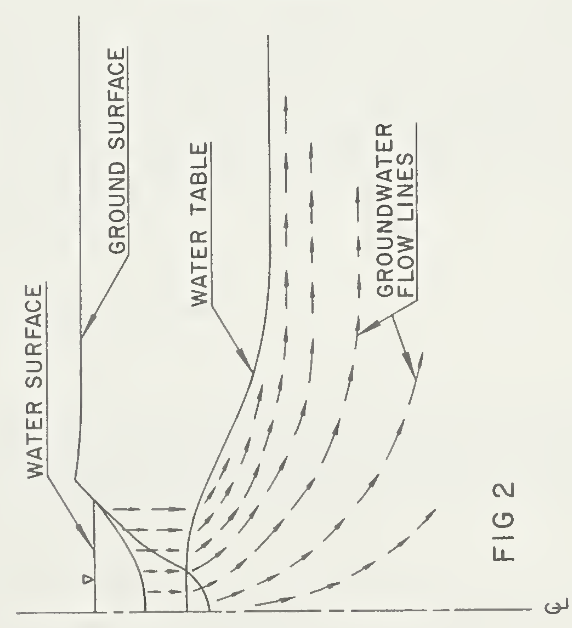

FIG 2

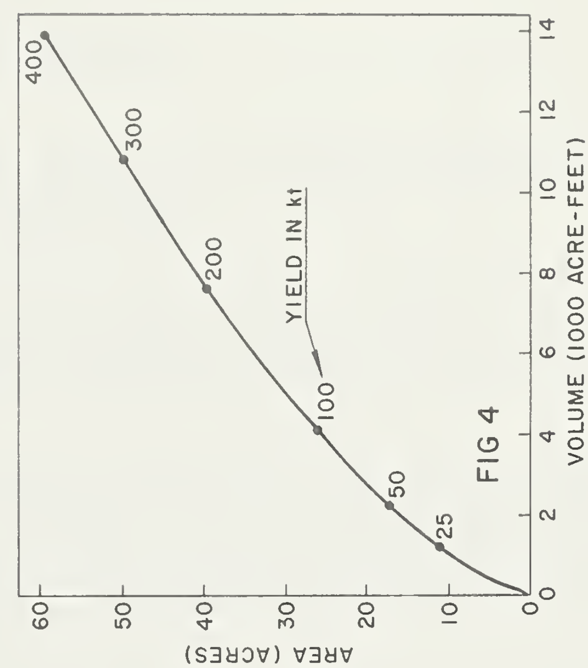

FIG 4

SOME PHYSICAL AND CHEMICAL CONSIDERATIONS IN ARTIFICIAL GROUND WATER RECHARGE

Leonard Schiff and Kenneth L. Dyer[1/]

INTRODUCTION

Augmenting the underground storage of water by artificial recharge provides a source of water for irrigation, industrial and domestic use and can halt intrusion of saline water along coastal areas.

Supplies for recharge come from runoff waters wasted to oceans and salt lakes and from imported waters excess to the needs of certain areas. Deep percolation of irrigation water and sewage effluents can also contribute to ground water supply. Sewage effluents will undoubtedly become an increasing supply for recharge.

Artificial recharge means deliberately putting water into basins, channels, ditches, pits, or shafts, or applying extra amounts of water on agricultural land (off season and/or possibly on crops) in controlled programs. Deliberate artificial recharge is distinguished from incidental recharge, the latter being seepage from natural streams and conveyance systems, and deep percolation from normal irrigation.

Artificial recharge is used or contemplated in many areas in the United States and is of particular importance in the Western United States. The State of California obtains more than one-half of its water from ground-water and appears destined to continue this practice. There are few economical surface reservoir sites left in California, particularly in areas of need. Demands for water are increasing. Because there are drought years and wet years, it is necessary to store more water underground.

INFILTRATION RATES

As in many soil-water movement problems a key factor in recharge is the infiltration rate or rate at which water can enter the soil. With an adequate water supply infiltration rates will depend upon water characteristics such as the amount and type of suspended material and chemical constituents, and

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1/ Research Leader and former Soil Scientist (Chemistry), respectively, Fresno Field Station, Soil and Water Conservation Research Division, Agricultural Research Service, United States Department of Agriculture.

upon soil characteristics such as texture or size of soil particles; soil structure or the arrangement of soil particles, both individual particles and clusters of particles; the resulting pore space and its distribution; the continuity and stability of pores; and chemical constituents. Stability of pores can be affected by the physical action of water as well as the chemical characteristics of the soil and water and their interactions. On a reasonably uniform soil the interface between water and soil at the soil surface appears to be the zone controlling the infiltration rate. A subsurface stratum with a percolation rate (rate water can move through a depth of soil) less than the infiltration rate may control the infiltration rate if saturation of continuity of flow exists between the soil surface and the subsurface stratum. Thus the stratigraphy or arrangement of strata becomes important.

INCREASING INFILTRATION RATES

Where surface soil characteristics limit the infiltration rate, treatments of soil and/or water -- whether physical, chemical or biological -- and operational procedures have been developed to increase the hydraulic conductivity and/or hydraulic gradient and thereby to increase the infiltration rate (Bliss and Johnson, 1952, and Schiff, 1955). Operational procedures developed suggest spreading water on land while infiltration rates are relatively high, and then drying this land for recovery in infiltration rates. Relatively high surface heads increase the hydraulic gradient. Minimizing tillage activities reduces breakdown of soil structure and soil compaction. Johnson (1957) reported on utilizing organic residues to increase infiltration rates. Bliss, Johnson and Jans (1958) discussed the use of ferric sulfate to increase infiltration rates and compared results obtained with various chemicals based on experiments using infiltrometers. Schiff and Johnson (1958) and Schiff (1958) found grits and sand filter materials at least doubled infiltration rates into aquifer material. Pea gravels 1/8 or 1/4 inch in diameter had little effect.

SOIL CLOGGING AND ITS PREVENTION

Many rivers carry considerable sediment in flood periods, particularly during rising stages. Generally, such waters are not used for spreading for recharge since they will clog the soil and reduce the infiltration rate. Stabilization of channels not only reduces silting in storage reservoirs but also provides cleaner water for artificial recharge. Soil conservation measures which reduce runoff and soil erosion also tend to reduce the sediment load and clogging of recharge works. Sometimes flood waters are used for spreading during the declining stage, when they tend to carry less sediments or have lost some of their suspended load in reservoirs.

Major causes of soil clogging are: (1) sedimentation and (2) microbial sealing. Methods of handling suspended loads are described in the Proceedings of the Conference on Ground Water Recharge (Schiff et al., 1959, 1961) and include:

the use of grasses, detention basins, flocculation and detention in basins, and filtering; scraping or using suction to remove deposited materials; harrowing deposits of fine material to distribute with depth and subsequent removal by scraping. Pumping after injecting water into multiple-purpose wells used for irrigation and recharge in Texas removed only 7 percent of the clay injected. Hydraulic conductivity was six times greater in filters receiving water with flocculated suspended loads than in filters receiving untreated water.

Schiff (1961) reported filtration rates were more than twice as great when water flowed over a filter than when ponded on a filter. Raking the filters to a depth of about 1/2 inch caused deposited fines to go into suspension and be carried away by the flowing water, increasing the filtration rate and thus movement of water into model recharge wells. Model wells receiving unfiltered river water clogged. This approach envisions potential use of shafts or shallow wells, with overlying filter materials strategically spaced in water ways. The upper parts of the filter materials can be disrupted occasionally causing clogging deposits to mix with the flowing water and be carried away. Recovery in infiltration rate and increased flow of water into the shafts or wells are thus attained.

A basic approach to the problem of clogging by sediments is to cause sediments to deposit within "economical reach" of a scraping or other removal operation. Certain small amounts of deposited or hauled in silts and clays when mixed with original sandy materials can cause "controlled deposition." By occasional removal of these deposits an average, high, infiltration rate can be maintained (Schiff, 1958, 1961). It has also been shown that "turkey" grits and certain sand materials placed on top of original aquifer material doubled infiltration rates into the aquifer material, Schiff (1958). It may also be found to advantage to mix certain amounts of deposited silt and clay with original sandy material to help develop a soil that can support vegetation and still take water at a relatively high rate. Vegetative cover is helpful to the development of good soil structure and stability of structure. The grass cover on the Saticoy Spreading Ground in Ventura County, California maintains an open, friable surface soil and waters have been applied with a suspended load up to 550 parts per million and in a few instances considerably higher with no damage.

Microbial sealing is caused by the products of microbial activity and depends upon the amount and type of organic matter in the soil and the manner in which soils are wet and dried (Allison 1947, and Bliss and Johnson, 1952). When water is applied to soil after an appropriate drying period, infiltration rates tend to return to normal. However, if water is applied to soils that still contain considerable undecomposed organic matter, declines in infiltration can be quite rapid.

INFILTRATION RATES OF RECHARGE FACILITIES

Based on good watershed management and other practices already mentioned, reasonably clear water can be made available for recharge. For recharge basins in California receiving reasonably clean water Richter (1955) reported on relations between infiltration rates in feet per day and soil texture, which may be summarized broadly as follows: coarse-textured soils ranged from 1.6 to 10 with an average of 4.2, medium-textured soils ranged from 1.7 to 3.6 with an average of 2.2, and fine-textured soils were less than 1.0 with an average of 0.46. As mentioned previously, there are other factors that affect infiltration rates in addition to texture. For example, the medium-textured topsoil of the Saticoy Spreading Ground determines the rate of recharge since the sandy subsurface layers can transmit water at higher rates. The infiltration rate of 3.5 feet per day over a spreading season approaches rates of spreading areas with coarse-textured soils. This is due to the effect of the vegetative cover on soil structure and stability of structure. The grass cover also maintains an open, friable, surface soil and waters have been applied with a suspended load up to 550 parts per million and in a few instances considerably higher with no damage. The potential infiltration rate of a sandy loam surface soil at the Minter Field Spreading Ground near Bakersfield, California, is about 3.0 feet per day. However the percolation rate of the shallow less-pervious subsurface soil layers limits the actual infiltration to about 0.5 foot per day.

SOIL CHARACTERISTICS AND SOIL-WATER MOVEMENTS

Specific information on the characteristics of soil and stratigraphy must be known on each site considered. This information will become increasingly useful as work is stepped up on relating such information to water movements in the soil.

Various devices used in the field include manometer-equipped infiltrometers, moisture blocks (placed at selected depths below infiltrometers) and covered infiltrometers (for sampling for soil moisture change, down to field capacity, due to drainage alone).

Moisture change beneath the experimental Woodville, California Recharge Basin during 12 days of flooding was measured by the neutron moisture probe (Schiff 1961). Measurements permitted determination of the transmission rate, field capacity, field saturation within the water mound, and yield. Samples of soil and water taken from plots are used to determine physical and chemical characteristics of the soil in order that these characteristics may be related to movements of water in soil and soil-water chemistry.

When the percolation rate of some substratum is less than the infiltration rate a mound will develop and can restrict the infiltration rate when saturation or continuity of flow to the soil surface exists. This also affects lateral flow and salt movements in the profile. When substratum of low permeability limits recharge. Injection methods of recharge that include pits, shafts and channels, may be considered (Schiff 1954).

CHEMICAL ASPECTS

The stratigraphy influences the magnitude and direction of flow, which in turn affects the quality of the percolating water. Consequently, it is necessary to log the location, thickness, and continuity of the strata. It is equally important to determine the kind and distribution of salts and base exchange characteristics.

Ordinarily, locations will be selected for recharge where percolating water will move through strata with relatively little change in salt content in either the water or the soil. Recharge waters can be expected to increase in salinity before they reach the water table. Exceptions occur where recharge water salinity may actually decrease such as by salt sieving (Kemper, 1960); however, these exceptions are largely of academic rather than practical concern in ground water recharge. Concentration of salts in the recharge water is increased by the process of evapo-transpiration and by the process of solution. The effect of evapo-transpiration on recharge water quality is important where infiltration rates are low. Percolating water will dissolve essentially all of the highly soluble salts it contacts.

Deep soils with a high and fairly uniform salinity occur naturally in part of the San Joaquin Valley of California. Sprinkler irrigation for about 7 years has leached highly soluble salts to a depth of about 30 feet. The pattern of leaching in these soils follows rather closely the curves calculated by van der Molen's (1956) methods. These methods are based on Glueckauf's theory of chromatography.

The closest fit of calculated chloride ion profiles to observed profiles was obtained by using a theoretical plate height constant of 8 cm. (applicable to this type of soil) and by correcting for differences in chloride in concentration below the leaching fronts. The chloride ion concentration in the soil moisture below the leaching front is considerably lower in the unirrigated plot than in the irrigated plot. This is due to the fact that a much larger percentage of essentially salt-free moisture occurs in the comparatively dry unirrigated subsoils. (Bower and Goertzen, 1955, and Kemper, 1960).

Some of the highly soluble salts, which are logged in a chemical inventory, may not enter the mainstream of percolating water because they are retained in closed pores. One such case has been reported in the Tulare Lake Basin of the San Joaquin Valley by Biggar and Nielsen (1962).

Moderately soluble salts may be present in crystals or granules so distributed in the soil that they come in contact with only a small amount of percolating water. Leaching curves of chloride and sulfate ions in a soil from the San Joaquin Valley which contains granular gypsum have been developed. All the chlorides are leached downward but very little of the sulfates (largely present as gypsum) are leached. This indicates that the size and distribution of crystals and granules of moderately soluble salts must be considered in evaluating their influence on the quality of percolating water.

Most ground waters are saturated with a number of slightly soluble salts. In arid and semiarid regions examples of common saturating salts are calcium and magnesium carbonates and silicates. Slightly soluble salts such as these are not likely to produce a quality problem in respect to agricultural use of water; however, they may be of serious concern for some industrial uses.

The strata base exchange status strongly influences the cation chemistry of percolating water. Consider a stratum that contains 40 percent of water by weight and has a base exchange capacity of 20 me./100 grams saturated with calcium ion. If this stratum is leached with water containing 10 me./liter of sodium salts it can replace all the sodium in a volume of water 50 times greater than that held by the stratum. Many important aquifers have base exchange capacities far less than 20 meq./100 grams and some percolating waters are much more saline than 10 me./liter. In such cases the effect of strata chemistry on water quality will be less important than in the example given.

The chemistry of boron in soil-water is complex and has not been thoroughly investigated. Boron is usually leached at a slower rate than the highly soluble salts. For some soils the leaching of boron may be expressed approximately by the Langmuir adsorption isotherm (Hatcher and Bower, 1958). This infers that for these soils the boron movement is largely regulated by the process of ion exchange. Water moving through strata where ion exchange is the dominant process may either gain or lose boron, depending on the boron status of the strata and the boron content of the water.

Chemistry mentioned above has been concerned with the effect of soil and sub-strata on water. The water in turn has an equal and simultaneous countereffect on the chemistry of the soil and strata. Salts may frequently be precipitated on or near the soil surface. In recharge operations it is the slightly soluble salts such as calcium and magnesium carbonates that tend to precipitate. These salts precipitate because of evapo-transpiration and indirectly because of the resulting increase in soluble sodium, exchangeable sodium, and solution pH. Salts which have precipitated on or in a soil reduce hydraulic conductivity by mechanical clogging of soil pores. Increasing the salinity of the soil solution increases hydraulic conductivity (United States Salinity Laboratory Staff, 1954).

The hydraulic conductivity of silts and clays is appreciably influenced by the base exchange chemistry, whereas sands and gravels are practically unaffected. Percolating water can have a major influence on hydraulic conductivity by its effect on the soil exchange status (United States Salinity Laboratory Staff, 1954, and Reeve, 1960). In general, the higher the exchangeable sodium percentage the lower the hydraulic conductivity. A change of only 10 percent in the exchangeable sodium percentage of some soils may change infiltration rates several-fold (Reeve et al., 1954). The pattern of ion exchange between soil and percolating water has been described by Ribble and Davis (1955) and Bower et al. (1957).

A unit of percolating water may change its ionic equilibrium several times in the course of its flow. Each time percolating water changes in cation composition the boundary of substrata base exchange characterisitcs shifts in the

direction of the water flow. The distance of this shift is inversely related to the base exchange capacity of the soil, and directly related to water salinity and volume of water moving through.

In areas where ground water tables have dropped much can be inferred about substrata chemical characteristics from the chemical qualities of water pumped. Such information is useful in planning programs involving the best use of ground waters and imported waters and selecting areas for recharge.

Waters of good quality applied to a high sodium or sodic soil can severely reduce the hydraulic conductivity. Reeve and Bower (1960) have shown that saline water mixed with water of good quality can increase the hydraulic conductivity. The proportion of saline water in the mixture is gradually reduced until the soil is reclaimed.

Saline ground-water is available in some subsurface basins and percolating water will increase the volume of saline water in time in much of the west side of the San Joaquin Valley in California. This saline water will be useful in alleviating permeability problems anticipated when imported good quality water becomes available. Much of this water is also beneficial in the sense that it is high in gypsum and nitrates. However, such waters should be used in the light of soil conditions and in carefully planned programs.

DESIGN OF RECHARGE FACILITIES

The design of recharge facilities must be based on the physical and chemical characteristics of soil and substrata. Some water and salt movements associated with such characteristics have been discussed. Where possible, locations free from salt problems are selected. In some cases recharge facilities may be placed a considerable distance hydraulically upslope from wells they serve because of such considerations as cheaper land or coarser soils. Investigations can determine within reason how long it will take water to flow from the recharge area to wells in question. It may be desirable to install wells within and around the periphery of the spreading areas to minimize water losses and obtain water quickly. The pumped water may be brought to the area of need by a gravity system or pumped where necessary. The El Rio spreading ground constructed by the United Water Conservation District in California is an example of such an approach. Infiltration rates obtained with infiltrometers, Fig. 1, were close to those found subsequently for the spreading ground.

Based on a ratio of perimeters, more lateral flow will occur if a number of spreading areas are used rather than one large one. More lateral flow will also occur if each area is rectangular rather than square (Schiff, 1961). Most spreading areas require lateral flow to accomplish sufficient storage of water; consequently, it is necessary to know the storage capacity and hydraulic conductivities of substrata beneath the spreading ground and under adjacent lands.

In the rotational system of recharge, parts of an area are flooded when infiltration rates are high while other parts are being dried for recovery in infiltration rate. This system lends itself to soils of reasonably uniform top-soil and substrata characteristics or to soils underlain by relatively shallow, less pervious soil layers. In the strip system, strips or parts of an area may be used where subsurface layers limit flow. Water will accumulate and spread out laterally on a subsurface layer. Schiff (1954) suggested spacing strips on the infiltration rate-percolation rate ratio. If the ratio is 10, about the same amount of recharge could be obtained by using one-tenth of the land as by using the entire area. Strips treated to increase infiltration rates, or strips in the form of channels or shafts in the bottom of channels may further reduce the areas required. A desilting basin is a desirable addition to the spreading works if the water available for ground water recharge contains an appreciable amount of silt. The basin should be constructed with a slight upslope from the entrance to the discharge end. This slope facilitates ponding, allows control of detention time, and permits grasses such as bermudagrass to grow if a major portion of the plant remains above water. The grass cover helps maintain infiltration rates in the basin and thus, the basin itself may contribute significantly to recharge along with the spreading works proper. A desilting basin or some form of filtering may be essential if recharge is by use of wells, pits or shafts.

Replenishment irrigation is a relatively new approach and is defined as excessive irrigation of crop lands with surplus surface water. Preliminary observations indicate alfalfa can be over-irrigated during the dormant season (Hall, Hagan and Axtell, 1957); prolonged irrigation of cotton produced no significant differences in crop yields of Acala 4-42 cotton (Haskell and Bianchi, 1963). The method appears particularly adaptable when soils or substrata of low hydraulic conductivity are involved although a large area must be used for recharge.

Mathematical equations for rising and falling ground water mounds by artificial recharge were given impetus by Baumann (1952) who considered a two-dimensional condition, where length of spreading area is much greater than the width. He shows that for certain conditions the Boussinesq (1877) equation for unsteady ground water flow reduces to the analog of the heat flow and for steady flow reduces to the Dupuit (1948) equation. He presents a solution for the heat flow analog.

Marmion (1962) derives equations for various stratigraphic conditions and compares shapes of mounds obtained from these equations and from equations by Baumann (1952) and Glover (1961) with shapes obtained in a two-dimensional model representing a vertical section in an unconfined aquifer.

The depth, shape and extent of subsurface "control layers" not only influence the design of a system but also determine (1) the useable storage capacity of the subsurface basin, (2) whether or not the water table will build up and merge with the saturated zone extending down from the soil surface and thus limit infiltration, and (3) whether drainage problems will be created.

Certain recharge facilities can be designed for multi-purpose use, such as habitats for fowl and game, and as recreational areas and playgrounds.

CONCLUSIONS

Efficient, economical artificial recharge requires the logging of the physical and chemical characteristics of the soil and stratigraphy. It requires a knowledge of the relation of these characteristics to infiltration and the subsurface storage and movement of water. Recharge facilities should be made multipurpose whenever possible. Such facilities should be designed in the light of comprehensive plans for the conservation and use of water resources.

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GROUND WATER RESEARCH AND MANAGEMENT TECHNIQUES

CONCLUDING REMARKS

Leonard Schiff

Our Panel has considered some ground water research and management techniques. I believe good management of ground water is accomplished when coordinated with the storage and use of surface waters. I also believe the coordinated operation of ground and surface storage and use of water may best be accomplished in the light of comprehensive watershed planning for water resources. Comprehensive watershed planning seeks an optimum balance and a maximization of benefits to meet agricultural, industrial and domestic needs while considering water conservation, hydro-electric generation, flood control, recreation, fish and wildlife preservation, water quality control, the prevention of water shortages and the beautification of man's environment.

Imperative to technical planning, and the development of alternate approaches when required by political, social and economic considerations, are data on all major uses of water and on all factors of the hydrologic cycle (rain, runoff, moisture in the soil, ground water, evaporation, transpiration or the use of water by crops).

Hydrologic and other data must be collected and their relationships understood on each unit of area. A unit frequently may be a watershed and its sub-watersheds, where factors have a reasonably identifiable degree of interdependency. Sub-watersheds usually make up watersheds and watersheds make up river basins and river basins make up regions. People from the local level to the regional level should become interested and concerned as well as those representing private and public agencies in communities up to and at the national level. Under such approaches the effect of changes in land use on water conditions and movements may be predicted and projects may have maximum multiple use.

When shortages develop we tend to seek new sources of water and planners must consider such approaches but the maximum and efficient use of each unit of water would always seem to be in order and a challenge to a growing, efficient, economical society.

CONFERENCE ON GROUND WATER SECOND DAY

PRESIDING -- John R. Teerink, Assistant Chief Engineer, California Department of Water Resources

Good morning ladies and gentlemen. As the Biennial Conference on Ground Water gained momentum sponsors decided that it was necessary to look at the total picture of our ground water management problems and programs. Today our conference panels are going to discuss the fields of economics, law, quality, and the implementation program of our ground water basin operations management. In economic aspects, as man tries to maximize his gains while minimizing input, he tends to an orthodox approach. Yet those of us who work in the real world of water management know that the orthodox sometimes becomes quite academic. Nevertheless I believe that a thorough knowledge of economic criteria and data in the development of our water program is essential in the decision-making process. We owe our next Moderator a debt of gratitude for the fine work he is doing in the field of water. It is with pleasure that I turn the next part of our program on economic aspects over to Dr. Warren Hall.

In regard to our next panel efficient planning contemplates the conjunctive operation of surface and ground waters which accentuate problems concerned with rights to water. California's water litigation has been long and expensive and consumes considerable of our time and our interest and is the subject of our next discussion. We lock forward to the discussion on legal aspects by this fine group of panelists. Our Moderator James Krieger is certainly well chosen, Jim is a real lawyer's water lawyer. He is Chairman of the Southern California Water Conference, he has been instrumental in several significant pieces of legislation now being implemented with our ground water program. It is a pleasure to turn this panel over to Jim Krieger.

In the interest of time we'll get started with our afternoon session with a minimum of introduction, for that matter none is needed. Dr. P. H. McGauhey, Mack, and his panelists are well known to all of us and I know we will have an interesting and lively session on a most important aspect of water quality.

Our concluding panel will cover needs and try to answer the question "How do we accelerate action?" We know that when we try to pull the various involved facets of interests together to form a consensus of opinion to develop an action program we have a difficult job on our hands. We do have a qualified panel to go into some of the problems in getting water programs under way. Dr. McGauhey will continue on as Moderator.

ECONOMIC ASPECTS OF GROUND WATER USE AND MANAGEMENT

Moderator: Warren A. Hall, Director
Water Resources Center
University of California
Los Angeles, California

Aaron G. Nelson
Professor of Agricultural Economics
University of Arizona
Tucson, Arizona

Stephen C. Smith
Professor and Chairman
Department of Economics
Colorado State University, Ft. Collins

J. Robert Roll, Chief Engineer
Santa Clara Water Conservation District
San Jose, California

J. H. Snyder
Department of Agricultural Economics
University of California, Davis

Vernon E. Valantine, Chief
Operations Branch, Southern District
California Department of Water Resources
Los Angeles, California

Mr. Hall:

We are going to try to keep the session this morning on schedule. The same problems with lunch that would have occurred had we not secured early yesterday will occur again today, so we will want to stop promptly by the 11:40 recess. Consequently, I'm going to beg your indulgence and forego the usual detailed introductions of our panelists. Suffice it to say with respect to the men on our panel, if you don't already know them, you had better get acquainted with them.

I would like to introduce our Panel by name: Dr. Stephen C. Smith, Colorado State University, Professor of Economics; Professor J. H. Snyder, Professor of Agricultural Economics, Davis; Professor Aaron G. Nelson, Professor of Agricultural Economics at the University of Arizona; Mr. J. Robert Roll, Chief Engineer, Santa Clara Valley Water Conservation District, San Jose; and Mr. Vernon E. Valantine, Chief, Operations Branch of the Southern District, California Department of Water Resources.

The ground rules for this panel are that these experts are going to be given a very brief opportunity to speak their piece and then the subject will be open to discussion from all sides. We will try to develop a cross discussion so that a number of different points of view on each of these subjects can be developed at the same time. If the panelists start lagging, I'll just look out into the audience, and anybody who wants to needle one of these fellows will be permitted to do so. We will also work in the discussion as we go along, rather than wait until the end and then try to recall what the other fellow said.

As I sat through this meeting so far, and as I've sat through previous meetings on water and ground water, it has occurred to me that we often fail to keep track of the fact that there are a number of resources involved in ground water, not just the water itself. So, as a background for this discussion, I'd like to call the panelists' attention to some of my views on the matter of the resources that we are trying to manage. And, of course, when we say "manage" we mean "control for the purposes intended."

The first of these resources is our friend, the safe yield. This is a property right which the courts have recognized. Adjudication requires it in specific cases, but in any case there is the safe yield of a basin, and it is a resource that we must manage.

The second resource which we must manage, and with which we are all quite familiar, is the minable water which any basin contains at any one time. This is the water in a basin which could be removed but which would be in excess of the safe yield. This is the possible overdraft. It is a very valuable resource and it has been used to build a mighty economic complex here in Southern California. It is building a similar complex in Arizona and also in the central valley at the present time.

The third resource, that I would like the audience and my panel to bear in mind, is that the ground water basin is also a storage basin. It is a place where we can put additional water for storage. If you will express the available ground water storage in the state of California today, in terms of Oroville Dam, and its corresponding costs, you will see that this is a mighty resource, indeed.

These three resources are generally recognized. I'm not sure which of them besides safe yield are property rights. I would expect that there might be some property right attaching to the storage space under a man's property. I don't know what laws would apply to the minable water. But the next two resources are a little more difficult.

The first of these I call an energy resource--although it is an energy resource in reverse. Yesterday, we heard Mr. Skinner tell us that water levels in certain parts of Orange county were raised as much as 98 feet. This means that that water is pretty close to the surface. In terms of percentage of total pumping cost, those people who are removing water in that particular section will be quite happy to see that their power bills are drastically reduced by the fact that the district chose to purchase water from MWD and store it in the underground. The people on the other side of the basin, however, would not be quite so fortunate. So here is another resource that exists. When you put water in a basin you can change the energy cost of removing water from storage. I haven't made any calculations, but I would guess that some of the people in Orange County could pay a substantial portion of their pump tax just from the reduced energy costs for pumping in some parts of that district. Similarly, it might be that in other parts of the state we possibly could have justified earlier construction of the San Joaquin Valley portion of the Feather River Project if we had full ability to control the ground water basins in the area, simply by putting water in those basins to reduce the pumping costs.

The last resource we must deal with is the value of the aquifer as a transmission system in partial replacement for surface distribution systems. And again, Orange County is probably one of the better examples of this. A very large fraction of the water that is brought in to the County, both natural and imported water, travels through the ground to the wells and avoids an expensive, dendritic surface distribution system.

Now, with those five resources as a basis, I would like to turn to my panel, see if they would like to challenge me on any of those, or say, "Hall, you forgot the most important one of all." And, if not, I'll see what the audience has to say.

Mr. Smith:

Not necessarily to challenge, but to point out, that in the use of some of these resources--particularly the storage space in the reservoir, we do have certain criteria which affect the economics of this storage space, and the use of it. In addition to what Mr. Banks mentioned yesterday, that the economist was concerned primarily about efficiency and he wished that other criteria would come into mind, we do have to take other criteria in account, in the use of the storage space particularly, because of our ability to destroy this storage space by poor ground water management. We have two types of situations here. One of these is that we can physically destroy this storage space in an irreversible situation. This sets certain limits in making decisions on the management of this particularly resource and too frequently, we don't recognize this quickly enough.

This has been recognized in some places, I believe, such as the salt water intrusion problem which was mentioned yesterday. We also have situations of compaction which are irreversibly reducing the storage space and making it impossible to use this lost space in a physical sense. Probably the more important (and this will be taken up this afternoon) and also a problem which we may know considerably less, is the destroying of storage space by quality degradation, so that for one reason or another, the aquifer itself is not a usable aquifer. This sets a criteria that is important economically and to the management of the basin.

Another important element that is related to this is a different type of irreversibility. This element is the decision processes itself as it relates to the management. We have a set of decisions which are made and these decisions frequently are irreversible in a sense. Again we do not always take this into account in analyzing the over-all problem. When we say we make a decision, we either make a decision to do something or not to do something, and the effect of this is important in terms of the future.

Mr. Hall:

Steph, would you like to give an example of a decision of not to do something--where it proved to be irreversible in a sense, at least in terms of a value which was lost and will be almost impossible to recover?

Mr. Smith:

Well, it was pointed out yesterday, that we had in the Southern California area the potential for utilizing the storage space in the underground aquifers for quite a number of years, using the MWD facilities to a higher capacity than they were utilized. This was not done. This meant that you could not go back in time. The water was no longer there. Therefore, this brought pressure to seek other sources of water at a much earlier date than it might have been had all of the aquifers been filled to the fullest extent possible, using the full capacity of the aqueduct. So we have the irreversible kind of situation--you can't go backwards from here. When you're analyzing a particular problem, these kinds of irreversibilities need to be identified. I think that this is the main point, as limiting criteria for making your decision. And it may be just as important in making your decision as any particular types of an optimization plan in terms of any particular time.

Mr. Hall:

I have a question here from Mr. Valantine? Or a comment?

Mr. Valantine:

In spite of the fact that there are these possibilities of irreversibility involved in things such as whether we recharge or not, nevertheless, on the surface of it, it may not enter into a question of economics. The ground water in storage that was mined instead of surface facilities being used, meant that the pumping that would have been required to pump that replacement water from the Colorado River was saved and in place of it, the pumping lifts actually involved in lifting the water from the ground water basins was utilized. Unless we do make some use of the ground water in storage through mining and go beyond the safe yield of the basin, we are not really getting the value that is represented by the tremendous amount of water in storage. So that these irreversibilities do not necessarily represent economic penalties.

Mr. Hall:

There is another comment, I would like to throw in--to see if any of the panel can answer it. Suppose that with the present organizational structures or the organizational structures that existed at that time, it was decided by MWD that they would make water available for recharge purposes at essentially the marginal cost of getting it here, which I believe is about $6 an acre foot. And let's also assume that the people in these districts were foresighted enough to go ahead and buy that water for recharge purposes. If you didn't have any further restrictions it seems to me that there would be an undermining of the financial feasibility of the Metropolitan Water project because of what I'd call a short circuit. The people who are buying recharge water at $6 can put it into the ground and immediately pump it back out cheaper than the price for direct delivery. The usefulness of this use of excess capacity is predicated on the idea that the normal

demand will pay the "full price" (with quotes around it) for water. Yet we could have a short circuit whereby the people can get their water for substantially less than that. How would you go about blocking this, or do you think this would be a threat?

Mr. Valantine:

This has been a question in the state water project as well, as I'm sure many of the audience are aware, in that at the present time the state water project is set up with two basic classes of service. One is the delivery of project water, and the other is the delivery of surplus water. All parties were extremely concerned that the delivery of surplus water would short-circuit the repayment of costs necessary to repay the basic project costs. So for that reason, safeguards, we hope, have been developed in the agreement that the agencies that will be taking surplus water have accepted. They will take at least minimum quantities on a regularly ascending schedule of regular project water before they would buy any surplus water.

Mr. Hall:

So that it is blocked in the case of the Feather River project at least, I'm not sure this is true for MWD, Mr. Butler might be able to comment on that. The FRP delivery schedule precludes a short-circuit. They must contract for a delivery schedule and then they'll pay for it one way or the other, and we don't care, so to speak?

Mr. Valantine:

That's right.

Mr. Hall:

Was this true on the MWD? Was there a contract delivery schedule? Warren Butler.

Mr. Butler:

I happen to have been on the board of directors when the matter came up originally as Mr. Smith described it. The thing is that we debated that question no end, but there appeared to be no mechanics by which it could be accomplished in those days. I was intrigued by something Mr. Valantine said, and I wonder if that's what he really meant. Is he advising us that it might not be economically wise to do what has been suggested with the California aqueduct when the water arrives? That seems to me to be a very good question--whether we should buy the surplus water and use it to fill up our basins--or whether this is economically not the thing to do.

Mr. Valantine:

My remarks were directed towards the past, but the same question has to be raised in the future as well. In other words, it's just like everyone is for the good things of life, no overdraft, eliminate crime, this sort of thing, but all of these have a price connected with them, and maybe the price to eliminate overdraft is greater than what it is worth.

Mr. Smith:

I'd like to make a distinction here. We need to look at the question of pricing, and when I say pricing, I'm including here the ability of the local districts to levy a pump tax on the final user as well as the price charged by the wholesaler, in this case, either the state or MWD or what type of agency you have. (to the local district.) The total cost, pump tax plus the pumping costs will--in essence be the price that the pumper will pay as contrasted to surface delivery of water. This should be taken as something that is flexible over time. Now I realize that there are certain rigidities built into this process, but I think it can be taken as something that is flexible so that you can actually manage your basin. I'm not suggesting when I say these are irreversibilities, that you keep your basin always full or that this is the optimum level of basin management. The ground water basin would be pumped down or brought up depending on all other management criteria. But if you can use the pump tax (and I think we need some research on this point) as a management tool, how sensitive is it? I would suggest that possibly the situation that Mr. Roll has in his district, where the pump tax is not related to the purchase of importation water, but is related basically to the financing of the district itself, and can be adjusted within limits as a management tool--might offer some possibilities for further exploration, it might make it possible then to have the ground water basin managed over time in a fluctuating manner to suit whatever criteria the board of directors decided on.

Mr. Roll:

I agree. The pump tax has now been legally established, let's put it that way, but there have been lots of discussions on it. For example--the district I'm most familiar with is the Santa Clara Valley. Back in the 1920's there were some hot political arguments over the pump tax.

Mr. Hall:

Again we get back to Sen. Cobey's remark that when you can do something depends upon when you've adequately educated the population to the need. I think we've got to move along and drop the subject of irreversibilities or we will be irreversibly entrenched in irreversibilities and not get on with our program.

One of the problems that I see even in the example that we were mentioning, is that the land uses in Orange County and other places in Southern California

are quite different today than they were in 1941. As a matter of fact back in those days when I was going to Santa Ana Junior college we were driving through orange groves instead of house groves. Herb, can you give us some sort of idea how these things change this way. I know that you've been doing some work up at Davis on land use stability. What do you have to say about this?

Mr. Snyder:

(Editor's note: The statement read by Dr. Snyder with appropriate references has been utilized in lieu of the tape transcription.)

(Panel transcript continued.)

Mr. Hall:

Herb, I have a question I'd like to throw right back at you. Supposing we have a ground-water basin which is in reality overlapped by two local jurisdictions, let us say two counties. How does the system work if one chooses to simply sit back and not manage its resource and not manage its land? A Ph.D. thesis presented to a committee that I recently served on held that in all of these situations that require reasonable cooperation, there is almost inevitably a holdout, a man who hopes to profit by blocking action and forcing you to come to his terms. If you don't he will take the profit from you and leave you his problem. What comment would you make about that?

Mr. Snyder:

Well this is one of those problems that we have to live with, Warren, it's an institutional restriction. Our envisagement of this California Land Conservation Act supposes that the major use of it will be made by county governments at the local level, that the features of the program are such that these contracts are transferable from property owner to property owner at time of sale. They are also transferable from government jurisdiction to government jurisdiction so that if a contract is made for land while under county jurisdiction and while under county jurisdiction the land is annexed by a city the contract automatically becomes an obligation of the city and so forth.

We anticipate the major use of this program will be in the areas where there is today some element of stability in terms of land use. We are looking at this primarily from the agricultural land and the "prime" agricultural land standpoint and the attitude here is that this is the land for which we want to preserve for periods of time at least, elements of stability. It is this land that is most productive in terms of producing the agricultural output. It is this land that we want to keep. This is one of these long around-the-barn-to-get-to-the-door answers perhaps, but given this kind of complex, we are assuming and hoping that the local governments, although they may be different jurisdictions overlying the particular ground-water basin, will be desirous of bringing in this long-run economic base of agriculture and keeping the best land for agriculture while developing the plans for transfers of use for land which is less productive out of agriculture. I think this is an assumption, but it is also a hope, that this coordination and this commonness of goal will be an operating feature of the program.

Mr. Hall:

I was wondering, Herb, yesterday one of the speakers pointed out, going back again to our previous comments, that we did have an irreversible situation in that an area overlying the ground-water basin had been completely urbanized and this made recharge extremely difficult. Can this law assist us there in preserving certain of the best recharge areas from urbanization so that it will facilitate ground-water management even though the area may, over the next twenty-five years, become largely urbanized?

Mr. Snyder:

Yes, I think it most definitely can, because part of the program calls for the definition and creation of agricultural preserve areas. These preserve areas are defined in terms of agricultural and compatible uses and spreading basin areas are a compatible use under the terms of this program.

Mr. Hall:

One question that I would ask here though. If I were a farmer -- let's say that this was back in 1910 or '20 or whenever it was that Westwood was a good recharge area, supposing I was a farmer owning some of the more permeable outwashes here and I was trying to decide whether to keep my land in agriculture under this law or let it go urban and be taxed. Now I don't see how I, as an individual farmer, am going to accept a decision to preserve this for ground water simply because the darn sandy thing isn't worth a hoot for farming in the first place and I would be very happy to get a few seventeen-story buildings on it. How can we bring this into focus, not necessarily under the present law but under any kind of an arrangement?

Mr. Snyder:

Let me emphasize again that this is an enabling legislation and it features voluntary contracts and features local development of the program. This means that the majority of property owners in an area have in effect either to petition for hearings to create these preserves and create the possibility of contracts, or the board of supervisors on the advice of say, the county director of planning, has to propose this program and again go through the public hearing processes. It is a democratic majority vote-determined program and one holdout may be swept along as he frequently is in any district type of organization or zoning type of activity. If you go back to 1910, you would probably have been a good McKinley type farmer and you wouldn't have had anything to do with government anyway!

Mr. Nelson:

In Arizona we have quite a range in size of farms. It is my understanding in the agriculture in California you also have a similar range in size of farms. I believe the smaller farms tend to be less stable in terms of their ability to operate profitably. I'd appreciate some comments from Professor Snyder on the relationship of the size of the farms to stability in land use.

Mr. Snyder:

Well, I think as a generalization this is quite true, Mr. Nelson. If you are thinking specifically in terms of this program that I've mentioned briefly, there are certain size restrictions on the creation of agricultural preserves within which the contracting is possible. It takes at least a minimum of one hundred contiguous acres to establish a preserve and within this there may be farms of lesser size than that. Now if these farms are agricultural units, if they are producing

agricultural products on a commercial basis and if they are either on class one or class two soil according to the Soil Conservation Service use capability criteria, or if they produce an average of $200 gross agricultural product per acre per year, then they can qualify for contract and they can benefit from the stability program. But if they are on neither prime agricultural land from a physical criteria or if they do not produce this level of gross agricultural product then they are not eligible for contract. The enabling legislation permits the creation of preserves on the petition of property owners but without this contract provision, without any compensation. It's strictly a local agreement for a lesser period of time. Some stability can be built into this but again we go back to the alternative cost, the alternative pricing. Is the man better off or is the area better off in transferring or transisting its land use character from one to another. These are features that are going to be determined by and large by the local economy, the local farmers, and the local governments.

Mr. Hall:

I think that there's another point though that Aaron is aiming at. I probably shouldn't be saying this because I'm talking hearsay, but I heard, I'm sorry I cannot quote the source, a study was made in the Kern County area, I believe, of the profitability versus size of farm and it was found that the profit per acre of land increased linearly with size up to about six hundred acres and continued to increase beyond that. I think that part of what Aaron was trying to say, maybe he can correct me if I'm wrong, is that a small farm is in the stability squeeze a lot sooner than a large farm and therefore tends to turn over and become urban land. The owner tries to get rid of it, get out of it, because even without urban taxes he's in a tight squeeze.

Mr. Snyder:

Well, he can get out of it in at least two ways, Warren.

Mr. Hall:

One is to sell out to agriculture.

Mr. Snyder:

Specifically yes. Economies of scale are such that, other things being equal and in the broad overview, the larger the farm (up to some limit) the higher your profits. The higher your rate of return, the greater the ability of these farms to withstand varying rates of fluctuation of economic conditions.

But this has been true, I think, for quite a few years, and I think is also independent of either of the problems that we're talking about here. It can be viewed in the abstract as a simple scale problem in the same way that you can view the economics of the mamma-papa grocery store in consideration with Safeway, A&P, the Alpha Betas, Ralph's and the rest of them. And I don't think there has been any association for the preservation of the corner mamma-papa grocery stores that

has been lobbying for the stability for that type of economic activity. And by the same token, I don't think there is any great pressure or any great movement to protect, to preserve the heritage of the small inefficient agricultural firm. I think rules of thumb are kind of dangerous but it's something in the neighborhood that fifty per cent of our total agricultural production that's marketed in the United States comes from about ten per cent of the largest farms.

Mr. Hall:

I think I have a comment here from Aaron again.

Mr. Nelson:

The point that I wanted to bring out with this question is, it seems to me that we're moving to larger farms in the United States quite rapidly and I think that this in and of itself will lend to stability because, at least in Arizona, some work I have done indicates that the larger farms have very substantially larger earning capacity as return to land and water than the smaller units do, therefore, I think this would tend to contribute to substantial stability in agriculture that you wouldn't have on a lot of small farms.

Mr. Hall:

Aaron, why don't you take off here and talk a little bit about the effective level of ground water on your land values. We're supposed to be hanging on to underground water here. We will get too far above ground if we're not careful.

Mr. Nelson:

(Editor's Note: Because Dr. Nelson's statement centered on data and a chart, the following discussion and chart are substituted for the oral presentation.)

(Panel transcript continued)

Mr. Hall:

I'd like to ask one question. Maybe I shouldn't and no one has to answer this if they don't want to. But it's a question that we will be facing in the near future in searching our present water policies.

You mentioned here that you took a 480-acre farm and previously you mentioned the fact the larger the size of the farm the more the income. Presuming that there's some degree of accuracy to my hearsay report about rates of return increasing linearly with size up to about 600 acres, would you comment what the effect the 160-acre limitation in reclamation projects may have on the ability of a reclamation project farm to pay its fair share of the costs?

Mr. Nelson:

My personal opinion is that this limitation definitely needs to be revised, partly to help the American farmer to be honest so he doesn't have to go through all the schemes of trying to get around it.

Mr. Hall:

So that he doesn't have to embrace polygamy in order to get by!

Mr. Nelson:

I thought I had the figures here but I don't. The 140-acre farm that I considered under even current costs, prices, yields and so forth returned very little residual return to land improvement. On the other hand, the 1600-acre farm will give a greater return than what we have here on the 480-acre farm of course, somewhat more, not much more because most of the economies of scale are realized in the 480-acre farm. But I personally feel that there should be a revision made in the acreage limitation. In fact the work that we've done would indicate for a commercial farm probably 480 acres in crops is about the minimum they should have.

Mr. Hall:

Just to press a point a bit further, one of the comments that has always come up in terms of agricultural water policy is a suggestion that we look very hard at the free interest rate for water for agriculture. Would anybody care to attack the question of the relative value of the free interest versus the restriction on the net productivity of a farm by the 160-acre limitation? Is this a standoff or is it a subsidy as some people say or is the subsidy the other way around? I hear a great deafening silence, Mr. Valantine.

Mr. Valantine:

I think the Assembly Committee on Water put out a report about four or five years ago in which they studied the effect of the subsidy on the Central Valley project. That time they concluded that the price the farmers were paying of $3.50 actually represented water that was costing about $14.40. So on this basis there is about a $10 per acre-foot subsidy in this particular project which would go a long way to paying for the inefficiency of the smaller scale.

Mr. Hall:

I was speaking primarily in terms of the three per cent interest only. I think this particular subsidy comes under the provision that the price can also be set at what the agricultural can afford to pay. Is that not correct? Somebody can check me on this. I haven't made a calculation or anything to see what effect the three per cent has. Dr. Nelson's flow of benefits, presented here at five per cent, is sort of an indication. It may be that three per cent interest on the water project construction cost might be of the same order of magnitude as the gain that would be made by going to a larger size farm. I don't know. Warren Butler.

Mr. Butler:

Didn't Stanford Research put out a report here three or four years ago in which they contended that when you put in the interest-free subsidy the result was a change of land values that gradually equalized the situation for the farmers?

Mr. Hall:

I can't answer that positively that they did. Someone else may know of the report. But I think that the history of water development has shown that whenever there is some sort of a free benefit that is added as a step function, it's almost immediately capitalized. The history of the Los Angeles Aqueduct in the San Fernando Valley I think is the most dramatic of these. Land values jumped approximately one hundred-fold with the announcement that water would be brought from the Owens Valley. Now the subsequent people who came and bought that land were not the ones -- well they may have profited from the water but the big initial gain you see, was immediately capitalized. Now, it's a pet peeve of mine that we permit this. I think that if we adopt the proper policies in the first place, that is political policies, there can be essentially an announcement that these excess values will be taxed off over the future. As a result, purely speculative price raises would not occur and you would not have, as I think Howard Cook has expressed it so succinctly, "people who take the profit and leave the problem."

Mr. ________

I think this is very true, Warren. Another illustration of this is the value of cotton allotment that we have. I'm sure cotton allotment has a substantial value and the same thing is certain to be true with water. And I think

it's important. I feel quite strongly on this, that society should help to bring in water to develop an area, take the steps that are necessary so that the present farmers don't, you might say, reap all the benefits through the increased land values that accrue and leave the future farmers with the problems that you outlined.

Mr. Hall:

This brings up the question of how you organize to handle this. We have with us a man who has been too quiet so I'm going to put him to work now. Bob Roll, I'd like to have you comment on the value of special service districts to integrate surface and ground water and handle some of these problems.

Mr. Roll:

Thank you, Warren. Several of the speakers yesterday alluded to this necessity of a special district in order to handle an integrated surface and ground water management program. Perhaps the easiest way to understand how this works would be to take a look at an existing district that actually has been doing this for some thirty-six years. The district I refer to is the one that Cobey mentioned yesterday, the Santa Clara Water Conservation District.

One of the first problems that confronted the people who were trying to form a district, or rather, the people who were trying to solve the problem of a declining water table in the area, was how to achieve equity. In other words, how to equate the project beneficiaries with those who were paying the cost.

The solution that was finally arrived at and which was acceptable to both the agricultural and urban interests was to tailor a district to include only those people who could benefit by its functions and to levy an ad valorem tax on land only to finance the construction works and the maintenance and operation of the district. The reason this approach was adopted was the fact that the area was primarily an agricultural area. There was a reasonable uniformity in assessed valuations throughout the entire area. There was a reasonable equity between the assessed valuations of urban and of agricultural land so that by using land values as a tax base and tailoring the boundaries of the district to in effect the boundaries of the ground-water basin they were able to achieve public acceptance of the project that was finally put into operation.

One of the things that we ought to bear in mind is that quite often there are a lot of economic benefits that accrue from an integrated surface ground-water management program that are either not completely apparent in the beginning or that are not publicly recognized in the beginning. One of these is the necessity (and this has been mentioned by several of the other speakers) of maintaining an adequate ground-water level by recharging the underground basin from surface developed water, thus maintaining a sufficient level to prevent sea water intrusion. This is awfully hard for a lot of people to recognize until it actually happens and by the time it actually happens, it costs a lot more to prevent it than if it had been done earlier.

I think this is more or less along the line of what we were talking about earlier. If people had foreseen in the early days the necessity of recharging the underground here in Southern California when the water was available, they could have eliminated some of the problems that have subsequently plagued them.

One of the great economic benefits that accrues from such a management program by maintaining a high water table is the prevention of subsidence. In many areas this has already become a problem and in many more it will become a problem unless it's recognized early. In Santa Clara Valley the City of San Jose has subsided about ten feet since 1912. This is not apparent on the surface. It has taken place over such a large area that it hasn't caused differential settlement in buildings like you have in Long Beach. However, it has produced a large economic loss to the area in two ways. First, there has been an enormous amount of money that has had to be spent to correct drainage facilities, storm sewers, storm channels, natural creek channels, sanitary sewers that cross this subsidence area and have had their grades changed so that they are no longer capable of functioning as they should.

The second and perhaps the most important loss that has occurred to the area is one that wasn't recognized until recently. This was the damage to wells caused by subsidence. It's been estimated that about two thousand wells in Santa Clara Valley have been damaged. It costs anywhere from a thousand to two thousand dollars per well to repair this damage. Unfortunately, after you've once repaired it there's no assurance that the same thing won't happen over again unless we can stop subsidence. The only way this can be done is by bringing up the underground water table to a point where the buoyant effect of the water in effect supports the overlying weight of the material that's causing the subsidence.

Perhaps the most important economic benefit that we receive from a groundwater management program is the building up of what I like to refer to as a bank account. This is our reserve groundwater supply. In Santa Clara Valley we are very fortunate and we have two water importation programs, one already in operation and the other one well along on its way that will bring ultimately into Santa Clara Valley enough water to meet our entire future needs. However, these are both surface delivery supplies. In case of a man made or a natural disaster these could both be either interrupted or contaminated to the point where they were no longer useful. Unless we build up an underground supply while we have water available and recharge our bank account, we have nothing to fall back upon in case of such a disaster.

I mentioned earlier that the accepted method of allocating costs for this was a tax on land value. A special district must be flexible enough however to change as changing conditions arise and this has occurred in Santa Clara Valley. As the area changed from a primarily agricultural to an urban and industrial area several inequities crept into this method of allocating costs. As urban and industrial areas moved into one part of the Valley and not into another, assessed valuations changed tremendously.

We have cases where a farmer was raising pears, say, in the northern end of Santa Clara County on land that was assessed at $3,000 an acre and another man raising exactly the same crop in the south end on land that was assessed at $200 an acre. In effect one of them was paying fifteen times as much for his water than the other one, because they were paying on an assessed valuation of land.

This problem has been solved by switching from an ad valorem tax to a groundwater extraction charge or a pump tax as it's more commonly referred to. This has equalized the cost of water to all agriculturalists. It's also done another thing. The second inequity that had crept in by this urban expansion was that a lot of urban areas developed outside of the boundaries of the district. Municipal and private water companies were pumping water from wells within the district and serving these customers outside the district. Under our previous ad valorem tax method of spreading costs, these users outside the district weren't paying anything but were getting all of the benefits from the work that had been done by the people within the district.

When we switched to a pump tax this eliminated this inequity also because this imposed a tax upon the pumper. He transmitted this on to the water user through his water bill. In effect, what we've done, we've not added a new tax, we've merely substituted a tax that everyone formerly paid on their regular tax bill to one that they now pay on their water bill.

These experiences in Santa Clara Valley have pointed out the value of the special district which is designed only to include the area benefitted. It concentrates its efforts on a single problem, is in close touch with its members because it is governed by an elected board of directors and is flexible enough to change with changing conditions, can effectively operate and manage a coordinated surface groundwater management program.

Mr. Hall:

Did I see somebody who had a comment they wanted to throw in? Herb? You were looking at me like you had one. Maybe you just wanted me to look at the clock on the wall. It's getting awfully close to our termination time. I said we wanted to stay on schedule. Let's hear from Mr. Valantine about some of the financial aspects of districts and then take these two subjects together for a brief discussion.

Mr. Valantine:

Warren, I'd like to point out that I'm sure we're all aware of the fact that there is no intrinsic value in groundwater basins as such. The value comes from the use which we can put to them. If we don't use them they are of no value to the community. The use that we are considering, as you laid out in your beginning remarks, revolve around the management of the basin to extract water capable of being mined, to obtain the safe yield, to use the physical characteristics of the basin itself, its storage capacity, its transmissive characteristics and so forth.

The ways that these are used are to meet our present and future water demands. These demands can be computed on an annual basis or even down to an hourly basis and we can use groundwater basins in varying ways to meet these water demands. The uses can vary from a water distribution system completely dependent upon the groundwater system such as represented by a farmer who obtains all of his water supply from the ground, who has sufficient capacity in his wells, pumps and motors to meet his peak summer load and who does not do anything other than use the groundwater basin.

The same example applies to urban entities particularly in the mushrooming suburban areas around our urban centers in Santa Clara County, in L.A., Ventura, Orange County, everywhere where there is a groundwater basin that can be used. As the urban systems get larger, though, the operators of the urban systems find that they are paying excessively high power charges as standby demand charges for these pumps sized to meet only these hourly demands, and as their financial base increases they start interconnecting small areas of distribution to obtain a greater diversity and then to go into surface storage tanks and reservoirs.

However, many areas of our state do not have groundwater basins of sufficient magnitude for serving these purposes and they have to rely completely upon surface facilities. This one prime example is found in coastal San Diego County where the cities are completely dependent upon imported water and must regulate all of this imported water and distribute it to their customers.

In trying to use these two types of facilities we find a great potential for economic benefit to the community as a whole. This is where we integrate the capabilities of the surface systems together with the capabilities of the groundwater basin.

Earlier you mentioned, Warren, about the practice in Orange County, of spreading water and the beneficial effect. However, I don't think that this represents planned management as such because what we find is that water levels close to the area of recharge have risen dramatically while water levels in the heavily urbanized areas close to the sea coast have either remained static or have continued to fall under continued pumping. What is required is actually the next step beyond where we are today in the capabilities of our organizations to effect the optimum management. This is to get into the position where we can reduce the pumping, along the sea coast, for example, where the recharge to this area is limited by the pumping or by the transmission characteristics of groundwater basins. We do have the problem of trying to get the highest economic benefit from our groundwater basins. This requires us to make changes in our patterns of pumping or patterns of recharges and also perhaps the patterns of physical facilities actually constructed.

There is also a question of time involved. Many times we are faced with works that have to be constructed to meet an impending demand and we are aware that the groundwater basin itself could be utilized to a degree

but because the legal ability to use the groundwater basin in certain cases is not clear we do not try to use it. For example, a number of years ago we began to inquire as to whether or not groundwater basins could be utilized to regulate on a terminal basis, some of the flows of the California Aqueduct. However, it quickly became apparent that it would take a number of years and substantial study before the political climate of the State would be receptive to laws that would permit such an operation. Because we did not have this number of years and we had to have the system correlated and the water available, regulated and delivered within a short period of time, the State has gone exclusively to surface reservoirs. Even though we say on one hand that we cannot move on this level until we can produce the climate, many times we don't move at all because we don't have the capability of taking these actions.

Mr. Hall:

What you might say is the San Luis Reservoir is a monument to inability of the State as a whole to integrate its surface and groundwater systems. Maybe I shouldn't put it in that sense. I'm glad you brought these points up. You were almost reading my mind in trying to put to the panel the fact that there are four or five resources and maybe more. I do know that we have to look at managing all of them very carefully. I think that Vernon has put his finger right on this question when he says that it is not fully attained even in Orange County and Santa Clara County, which represent the show houses of groundwater management in the State today. You can be defeated in your purpose because not all of the resources that we're dealing with have been taken into account. At the present time these districts are doing all they are legally empowered to do, but we still have this continuing problem.

I think this is very closely related to the paper we heard yesterday from the gentleman from Israel where a groundwater basin is managed so as to get the maximum out of the basin from the total resource point of view. As I sat and heard that paper, each one of the questions that I wanted to raise he proceeded to answer.

Well, ladies and gentlemen, I don't want to cut this panel off and I know that we could sit up here and spend two hours each discussing economics of groundwater basins and when we got all through we would be only ready to start over on the second round. But our good Chairman only gave us until about eight minutes ago. He started us fifteen minutes late so I chiselled half of the difference. If John will permit me, I will just ask you to go directly for your coffee break and get back here as promptly as you can. Keep your eye on your watch. We'll see if we can put this show back on the road in fifteen minutes.

WATER RETURNS AND VALUE AS RELATED TO SELECTED FIELD CROPS AND SIZE OF FARM

by

Aaron G. Nelson[1]

This paper deals with water used on pump irrigated cotton farms in central Arizona. The objective is to present an analysis of return to water over variable costs produced by various field crops and the value of water as related to size of farm. Throughout the analysis present value of the residual return to land and improvements is taken as an indicator of the value of water, since land without water has little value for agricultural purposes in central Arizona.

Basic data for the analysis were obtained primarily from a recent study of costs and returns on cotton farms in central Arizona.[2] The central core of the analysis is based upon a typical pump irrigated farm with an initial pumping lift of 400 feet and 480 acres in crops. The initial cropping pattern includes 264 acres of upland cotton, 43 acres of alfalfa hay, 120 acres of barley, and 53 acres of sorghum grain. Production practices, costs, yields, and prices relate to the fore part of the 1960s. Specific figures on yields, commodity prices, water and fertilizer applied are as follows:

	Upland Cotton	Alfalfa Establish Stand	Alfalfa Hay	Barley	Sorghum Grain
Yield per acre	1,150# lint	--	4.25T	3,300#	4,100#
	1,775# seed	--	$6.50,pasture		
Price	31.5¢# lint	--	$25.00T	$2.35 cwt	$2.05 cwt
	$48 T seed	--			
Water ac. in.	60	18	51	30	33
Fertilizer					
Nitrogen #	120	5	--	64	72
Phosphorus #	30	50	15	24	20

The yield of alfalfa and the associated application of water are relatively low since in much of the pump irrigated area of central Arizona water is used on cotton in the late summer period, with alfalfa being left dormant.

Returns to Water Produced by Various Field Crops

With the level of costs and returns outlined above applied on a farm with 480 acres in crops, income over variable costs (including water costs) per acre-foot of water applied is as follows: cotton $34.77, alfalfa $3.35, barley $7.30, and sorghum grain $5.79. With returns to water from cotton being so much larger than returns from other crops, an obvious question is: Should production of alfalfa and grain be discontinued to save underground water for cotton production? Two major

[1]Professor of Agricultural Economics, The University of Arizona, Tucson.

[2]Nelson, Aaron G., Costs and Returns for Major Field Crops in Central Arizona, Arizona Agr. Expt. Sta. Tech. Bul. in process of publication.

considerations are involved in this question. First, what would be the effect on cotton if production of alfalfa and grain were discontinued? Second, would it be profitable to discontinue production of alfalfa and grain and use the underground water saved to produce cotton?

To my knowledge, we do not have the complete answer to the first consideration. Production specialists are of the opinion that a crop rotation helps reduce or eliminate various diseases in cotton. It also helps maintain needed humus in the soil. However, they also concede that as alfalfa and grain production become unprofitable they probably will be dropped from the rotation, probably without much effect on cotton. There are some indications this is happening in central Arizona, judging from the amount of idle cropland, and from the fact that some farms produce only cotton in rotation with fallow.

I have not had the time to explore the second consideration at any length. Three observations might be made, however. First, with the present cotton demand situation and acreage allotment program, underground water used for alfalfa and grain production probably could not be profitably used currently for cotton production. Second, it appears unlikely that it would pay, in terms of present worth of future income, to save underground water for future cotton production. Third, eliminating production of alfalfa and grain would reduce the rate of decline in the level of underground water and, therefore, reduce the rate of increase in cost of pumping. However, variable costs plus added capital costs involved in following the declining water table amount to less than 7 cents per acre-foot of decline. The average annual decline in the level of groundwater in much of central Arizona is about 8 feet. Thus, even if elimination of alfalfa and grain production completely eliminated the decline in groundwater--which it would not do--the cost of pump water for cotton production would be reduced by $0.56 per acre-foot, which is less than the income over variable costs produced by alfalfa or grain crops. It should be observed, however, that at some point of time in the future it would pay to eliminate alfalfa and grain production in order to reduce the rate of decline in the groundwater level.

Present Value of Water for Irrigation

In central Arizona the value of land for agricultural purposes is closely related to its water supply. Thus, the value of land and improvements for agricultural purposes is indicative of the value of underground water for irrigation.

In an area with an anticipated perpetual income at a constant level the indicated value of land and improvements for agricultural purposes--referred to subsequently as the capitalized value--can be obtained by capitalizing the residual income to land and improvements, using the well known equation,

$$\text{Value (V)} = \frac{\text{Residual income (R)}}{\text{Capitalization rate (r)}}.$$

The problem is more complicated in pump areas with a declining level of groundwater. Assuming all other things remain constant over time, a decline in the level of groundwater causes an increase in pumping costs and a decrease in the residual return to land and improvements. In such cases an appropriate equation to use is

$$V = \frac{R_1}{1 + r} + \frac{R_2}{(1 + r)^2} + \frac{R_3}{(1 + r)^3} \ldots\ldots \frac{R_n}{(1 + r)^n}$$

where V and r are defined as above and R_1, R_2, R_3 and R_n represent residual income to land and improvements the first, second, third and n^{th} year.

[illegible] alfalfa [illegible] cotton [illegible]

In any [illegible] of the [illegible] alfalfa [illegible] cotton [illegible]

I think [illegible] in the light of the foregoing [illegible] considerations [illegible] alfalfa and [illegible] cotton production [illegible]

Present Value [illegible]

In general [illegible] the value of land [illegible] closely related to the water supply. [illegible]

[illegible] the value of land [illegible]

[illegible]

The problem [illegible]

[illegible]

where V and r [illegible]

Using the farm with 480 acres in crops discussed above, together with yields, prices and costs as outlined, the capitalized value was computed assuming the pumping lift increased 8 feet annually. The initial cropping system was as outlined above: cotton 264 acres, alfalfa 43 acres, barley 120 acres and sorghum 53 acres. Each crop was dropped from the rotation when variable costs exceeded gross income. The additional idle land was assumed to remain in the rotation as fallow. Yields, commodity prices, and variable costs were held constant over time except for costs of pumping water.

In an area where the water table is declining, "added capital costs" are involved in pumping water in addition to the usual fixed and variable costs. In central Arizona wells customarily are drilled and cased initially to a depth so deepening is unnecessary. However, periodically additional column, bowls and motor horsepower (assuming the power source is electricity) must be added. These are capital expenditures and normally would generate fixed costs. However, in the case of a declining water table they are of the variable cost type; for example, if the well is to be operated the added capital expenditures are necessary. Thus, fixed costs of the well and related equipment were held constant in the analysis. Added capital costs, which amount to about 5 cents per acre-foot per foot of decline--about 40 cents per acre-foot with an 8-foot increase in lift--were included along with variable costs of pumping water. Variable costs amount to about 1.9 cents per acre-foot per foot of lift. Thus, with an annual decline in the groundwater table of 8 feet, variable costs increased 15.2 cents per acre-foot annually.

Fixed costs, variable costs (including the added capital costs), and the residual return to land and improvements for the 480-acre farm are portrayed in Figure 1 for the 100-year period, 1965-2065. Variable costs gradually increase over time due to the increased lift associated with the declining ground water table. Variable costs of producing alfalfa hay (including one-third the cost of establishing the stand) increase to the point where they exceed gross income in 23 years (1988). Thus, production of alfalfa hay was discontinued at that time, which accounts for the sharp drop between 1987 and 1988 in gross income and in the total of variable and fixed costs. Fixed costs decline slightly primarily due to elimination of "specialized" haying equipment. Grain sorghum drops out at the end of the 38th year (2003) and barley at the end of the 48th year (2013). For these crops fixed costs were reduced to account for "specialized" machinery used in their production and for a small part of the other fixed costs. Cotton does not "drop out" during the 100-year period in the sense of variable costs exceeding income. However, the total of fixed and variable costs exceed gross income in the year 2058, leaving no residual return to land and improvements.

Using a 5-percent discount rate, the present value of the residual return to land and improvements portrayed in the figure (1965-2057) is $311,155 or $648 per acre in crops. Since land in central Arizona has little value for agricultural purposes without water for irrigaion, a large part of the $648 represents the value of underground water.[3]

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[3]It is recognized that higher return crops such as vegetables and citrus probably will replace at least part of the land now in alfalfa and grain, with the result that the residual return to land and improvements and the capitalized value may be increased. It was not feasible in this short paper to include this type of analysis.

[illegible]

[illegible]

[illegible]

Using a 5-percent discount rate, the present value of the residual return to land and improvements portrayed in the figure [illegible] is [illegible]. [illegible] without water for irrigation, [illegible] of [illegible] water.[1]

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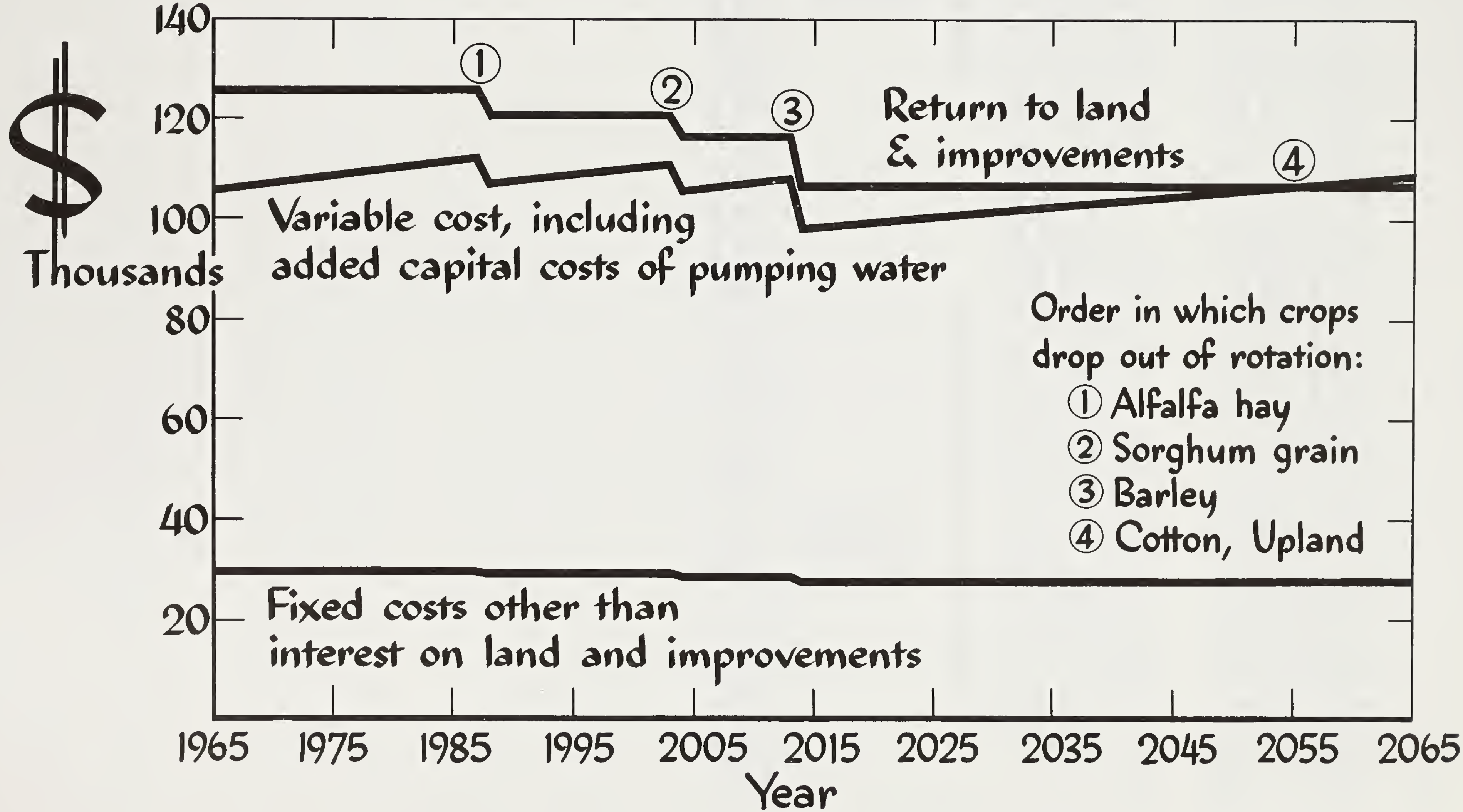
[1] It is recognized [illegible] the land and [illegible] result that the residual return to land and improvements [illegible] may be increased. [illegible] to include this [illegible] analysis.

Estimated Variable & Fixed Costs, and Residual Return to land & Improvements for a Pump Irrigated Farm with 480 Acres in Crops in Central Arizona



A farm with 480 acres in crops and a perpetual residual return to land and improvements at the 1965 level would have a capitalized value, at a 5-percent rate, of $884 per acre in crops. The difference between the $884 and the $648, or $236, is primarily due to the decrease in the residual return to land and improvements associated with the decline in the groundwater level. Termination of residual income at the end of the year 2057 served to reduce the capitalized value slightly, but the effect is negligible since the present value of income so far in the future is very small.

With similar cropping systems, residual income to land and improvements varies greatly from small to large farms. The study of costs and returns in central Arizona, referred to in the introduction, provides comparative figures by size of farm, as of the early 1960s. With variable costs of water at $8.50 per acre-foot and depreciation of the well and equipment at $11.00 per acre in crops, annual residual income to land and improvements for five sizes of farms is as follows:

Acres in Crops	Residual Income per Acre in Crops
140	$ 7.17
280	23.20
480	39.63
880	48.08
1,600	55.32

Obviously, the present value of future residual income to land and improvements would be low on the smaller farms compared with the larger farms. In other words, with similar cropping systems groundwater has a much lower value to small than to large farms.

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STABILITY IN LAND AND WATER USE -- AND ECONOMIC ASPECTS OF GROUND WATER USE AND MANAGEMENT

by

J. Herbert Snyder*

A discussion of stability -- to my mind at least -- necessitates or at least implies a condition of scarcity for the particular resource or resources under consideration. Furthermore, the role of the economist in discussing stability problems implies not only the scarcity element but also either pricing or allocation alternatives. Thus, in attempting to secure stability, one must start from conditions of scarcity, uncertainty, and conflict.

Scarcity of water in the West may be classified as either scarcity in time or space. In California and other of the arid and semiarid states, the natural rainfall occurs during the winter months of the year and the agricultural demand for water -- necessary to support plant growth -- occurs during the summer and fall dry-season months. At an early date of our agricultural experience, storage of water during the wet months for use during the dry months was a characteristic solution of the temporal scarcity problem, and we are still dependent upon this type of solution. The resolution of the spatial or locational dimension of the scarcity problem started with small and quite localized transfers of water from points of occurrence to points of use and has expanded to the point where even the NAWAPA proposal of the Parsons Company is not an altogether impossible type of solution.

The use of gound water -- or perhaps more accurately, the use of ground-water storage -- was extensive during early years of agricultural development as an element in the solution of temporal scarcity problems. In certain ground-water basins, the storage capacity is now being used -- and plans for greater future use exist -- as a component of regional solutions of the spatial dimension of scarcity. Thus, ground water *per se* and, more importantly, ground-water storage are vital components in any attempt to provide long-run stability for western water development and use.

In the short run -- and for purposes of this discussion, we are not restricted to single-period clock time, but rather to single-period planning intervals which may be fifty years or even longer in terms of clock time -- ground-water basins have supplied water to agricultural and nonagricultural uses to overcome both temporal and spatial scarcity problems. Various conditions of overdraft -- developmental, seasonal, cyclical, long-run, and even

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critical -- have been observed in the West.1/ So long as the cost of developing and using this water has remained below alternative water supply costs, ground water has been used and in some cases mined. This has, in turn, created concern over stability of use.

Other panel members have and will develop various elements of the stability problem regarding ground-water management _per se_. I would like to turn to a consideration of the associations between stability and ground water use -- and all water use for that matter -- and stability in land use.

For many years water costs have in reality been a minor component of total costs in the production of agricultural commodities. Furthermore, analyses of the economics of agricultural production reveal that the marginal value product of water in agricultural production is relatively low when compared to nonagricultural production. For example, an examination of some seventy-five California crops revealed that for only ten crops did the water cost amount to more than ten percent of the average total cost of production for those crops -- but some forty-eight crops were revealed for which the total water cost was less than five percent of the total cost of production. On an acre-foot basis water is an inexpensive factor of production: e.g., in the Salinas Valley of California, the heart of the vegetable production area, producing specialized crops, we find that the range in water cost for pumping ground water is from $4.00 to $12.00 per acre-foot, but there are some important regional differences even within this Valley.2/ In the San Joaquin Valley water costs may range even more widely from as low as $1.50 per acre-foot to as high as $27.00 per acre-foot,3/ but the important point to be made here is in the change through time of water costs as much as it is in the absolute level of these costs. In other words, the lack of stability in water costs is really the more important consideration. For example, in the San Joaquin study previously cited, it was observed that over the last ten-year period in Kern County the average costs of pumping ground water have increased by nearly $8.00 per acre-foot. Municipal and industrial water costs, on the other hand, range more typically in the $40.00 to $75.00 per acre-foot category with costs ranging upward of $100.00 per acre-foot not uncommon. Although the cost is somewhat greater, so has been the stability in these costs, thus making efficient and effective forward planning and decision making by water users in the industrial and municipal sectors more feasible and more easily accomplished than for those in the agricultural sector. There is then a real difference -- in dollars and cents -- between the competitive abilities of agricultural and nonagricultural water-use categories, as well as in the stability of these costs.

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1/ Snyder, J. Herbert, _Ground Water in California -- The Experience of Antelope Valley_, Berkeley: University of California, Agricultural Experiment Station, Giannini Foundation, Ground Water Studies No.2, February 1955,pp.81-97.

2/ Moore, C. V., and J. H. Snyder, "Pump Irrigation Cost Increases in Salinas Valley," _California Agriculture_, Vol. 19, No. 8, August 1965, pp. 14-15.

3/ Moore, C. V., and J. H. Snyder, "Irrigation Pumping Lifts in the San Joaquin Valley," _California Agriculture_, Vol. 19, No. 10, October 1965.

The differential may be made even more dramatic when one considers the probable scarcity of water resources in the long run. Assume, for the moment, that the problems of integrated ground-surface water resource development in use are resolved, that California has some fifty million acre-feet of water available each year for consumptive use requirements, that our potential irrigable acreage approximates fifteen to seventeen million acres, and that the California master water plan is economically feasible and justified. It is not unreasonable to conclude that we have ample water to meet agricultural requirements -- which, parenthetically, is quite different from agricultural demands. Such a conclusion, however, further implies -- if not assumes -- a virtual stagnation in every dimension of economical activity except agriculture. With present net population increases in California of twelve hundred to fifteen hundred people per day and present losses of agricultural land to nonagricultural use averaging a three hundred fifty to three hundred seventy-five acre farm per day, the future portends increased competition for water and land resources with ever increasing strength on the side of the non-agricultural sector.

We have all observed the many undesirable consequences of unconfined, uncontrolled, and uncoordinated urban development into agricultural areas. We cannot -- and for that matter we probably should not try to -- stem the tide, but the competitive ability of agricultural land and water users creates serious problems for the resource economist, engineer, lawyer, and political scientist as well as for the economy. Management of the resource is made more difficult, more expensive, and frequently more unstable.

The major difficulty seen for the future lies not with the fact of increased competition between agricultural water and land uses with nonagricultural water and land uses but with the manner of the fact. The manner of the fact can most readily be seen in the competition for land between agricultural and nonagricultural uses, which is further reflected in water use competitions and in stability problems for those responsible for developing management strategies for the water use. The most pressing need for the immediate and long-run future is for the provision of a more stable and favorable economic environment in which economic growth and development and planning for resource management can occur.

I am happy to report that a significant portion of this need will be at least partially met through the California Land Conservation Act of 1965 (AB 2117, Williamson) which becomes effective September 17, 1965.4/ The enabling legislation that structures this land-use control program features the exchange of long-term, nonagricultural development rights by voluntary contract between land owners and local government. The need for brevity compels me only to mention that this program holds out the promise of providing desirable elements of both stability and flexibility in land resource use and development that will encourage and permit more efficient and efficacious resource planning under conditions of economic growth for our limited prime agricultural land

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4/ Snyder, J. Herbert, "The California Land Conservation Act of 1965 -- A New Approach to Problems of Agricultural Land Use," California Agriculture, Vol. 19, No. 9, September 1965.

as well as for the water resources associated therewith. It is envisaged that this program will provide for greater certainty of future timing of transfer of land and water use from one use category to another, both within and between regions. It will also permit greater refinement in the economic analyses necessary in effective water resource development planning. The development of management programs for ground-water basins will be made easier by the introduction of certainty components regarding the character and timing of overlying land use.

Coordinated with other enabling legislation relating to local control and management over resources such as the Porter-Dolweg Act, I hopefully anticipate more effective and, with careful economic planning, more efficient local management of both land and water resources. I agree with an earlier speaker who said, or at least whom I understood to say, that we will not require the super agency in order to provide for better local ground-water resource management.

September 28, 1965

PANEL DISCUSSION ON LEGAL PROBLEMS OF GROUND WATER DEVELOPMENT AND MANAGEMENT UNIVERSITY OF CALIFORNIA AT LOS ANGELES SEPTEMBER 1 and 2, 1965

OPENING REMARKS OF JAMES H. KRIEGER, Moderator

Best, Best & Krieger, Attorneys at Law, Riverside, California

The thrust of the conference emphasizes the intensive job going on by experts who are analyzing ground water basins geologically and hydrologically. New attention is being given to these problems by economists and those persons specializing in the organizational aspects of ground water basin management. At the same time it has been suggested, sometimes facetiously and other times quite seriously, that the laws governing ground water management are antique and that we attorneys are somehow standing in the way of progress that might otherwise be made if we were only to permit the new concepts to have full expression. In rebuttal it would be easy to cite instances in which the legal profession, in combination with engineers, geologists, economists and others, has tried strenuously to change the laws that are now on our books. We are met by a host of objections from those who believe that water rights constitute a property right and must be protected.

If it is true that the right to pump water from the underground is a property right which must be respected, it follows that those people who over a period of years have developed an economy by pumping water and putting it to beneficial use are entitled to use the local ground water instead of the more expensive imported supplemental water which may be made available to them from a number of sources. The theory is that those who have built the economy by the prudent use of the ground water are entitled to continue to extract a share of that local supply, while those who come more recently into the developed community should be made to pay for the expensive imported water supply. It is within this framework of respect for water rights as a species of property that we have developed the cumbersome but necessary system of adjudicating water rights.

If this analysis is correct perhaps the members of this panel will address themselves to certain fundamental concepts which underlie the whole institution of adjudication of water rights. So I would throw out in the course of this discussion at least three key questions for the members of this panel to chew on. They need not confine themselves to these questions, but in aiming at answers to them I am sure these skilled men would be able to develop many aspects of the subject which will be useful to all of us.

First Question: Is it proper that a water right is treated by our courts and our society as a property right? Perhaps there is some other way to handle the right which an individual has to pump water out of a ground water basin and if so how can some other kind of treatment square itself with the free enterprise system?

Second Question: Mr. Robert Skinner, the General Manager and Chief Engineer of The Metropolitan Water District of Southern California, spoke earlier about the availability of some 16,000,000 acre-feet of water on an incremental basis from 1972 until 1990 under the State plan. He suggested that possibly water could be purchased from the State on a very attractive basis, and stored in the underground basins in Southern California. From an engineering and hydrologic viewpoint this seems like a sensible idea, and indeed it has been suggested on numerous occasions by water leaders. However, the question that always seems to stand in the way of this undertaking is again the question of property rights. Who owns the water storage capacity in the underground? Is it the overlying owner? May it be used by the person who first stores water in the underground? Is there any system of priorities governing it? Could the State use the underground as terminal storage capacity for State Project water; or could The Metropolitan Water District of Southern California use that same capacity to enhance its distribution system to its member agencies? Who must pay for the use of the underground, or is it free? These are some of the questions concerning the character and right to use the underground for the storage of imported water that the panel may choose to discuss.

Third Question: The most bewildering aspect of ground water management is the mass of agencies, public and private, which either deal with the problem or might deal with the problem of management. We have a vast assotrment of public agencies in California, many of them with substantially the same powers, and many of them overlapping one another. Vertically, we have the local agency and on top of it the larger agency, such as The Metropolitan Water District of Southern California, sometimes counties and cities. And then we have the State Water Quality Board with its various regional water quality boards encompassing the entire State. Another vertical institution is the State Water Rights Board. And on top of that we have the vast Department of Water Resources of this State. This is not to mention the various federal agencies that are concerned with comprehensive planning of our water resources. And this complex of authorities concerned with the overall water management problems of the State lead us to this question: What is the best method of integrating horizontally and vertically all of the agencies having to do with ground water

management? Many possible answers suggest themselves. For example, the powers of existing agencies may be increased. Most local agencies enjoy the power to enter into contracts with other agencies to effect joint purposes, a power that is frequently referred to as the "joint powers" authority. Should these provisions of the law be used instead of substituting new agencies or perhaps even creating a new agency to handle the problems of one or more existing agencies. It has even been suggested that a super agency is needed to coordinate the multiple activities of existing agencies. Without suggesting the wisdom of such a master agency, certainly there has been enough comment to justify an analysis of the merits of such a proposal.

With the outlining of these three questions I take great pleasure in introducing to you the several members of our panel. You will note that we have reached beyond the legal profession and in addition to the lawyers on this panel we are pleased to have a consulting engineer, an hydrologist, and an economist. These people were carefully selected to participate in a panel concerned with the legal aspects of ground water management because we believe that the concept of management reaches into every aspect of ordered life. All of the disciplines must here come together if a proper solution to this challenging problem is to be approached.

REMARKS OF WILLIAM H. JENNINGS
VICE-CHAIRMAN OF CALIFORNIA WATER COMMISSION
Jennings, Engstrand & Henrikson, Attorneys at Law
La Mesa, California

Two of the questions proposed by the Chairman may be analyzed in terms of the present situation in Southern California with respect to the underground storage of water. While it is true that each underground water basin is unique, and presents local problems peculiar to it, which demand local examination and local control, there are compelling reasons to recommend the activity of an agency which has the power over several of these ground water basins. For example, at the present time several of the member agencies served by The Metropolitan Water District of Southern California overlie vast storage basins capable of handling huge quantities of imported water for terminal storage and regulatory purposes. In some of these basins replenishment programs are being conducted under which water from the Colorado River is being imported to recharge the depleted local water reserves in these areas. Because of the present urgent demand for replenishment of ground water basins The Metropolitan Water District sells water to each of these agencies at a reduced rate, and that replenishment water is used to recharge the

basins. As a practice in itself this procedure cannot be condemned. Yet the result of this practice is to subsidize certain local agencies at the expense of all of the taxpayers in The Metropolitan Water District. Certainly there would be no ground for complaint if the agencies participating in underwriting the expense were assured of participation in the benefits therefrom in time of shortage. This might be accomplished either by direct withdrawal or by taking additional water from surface deliveries in exchange for the underground supplies. In that event, the agencies with access to underground supplies would be required to rely upon those reserves and release surface supplies to those contributing to the underground storage through the rate subsidy. The inequity of the present situation is highlighted by the fact that those agencies which overlie natural ground water basins are permitted to buy water from The Metropolitan Water District at a reduced rate called a "replenishment rate". On the other hand member agencies in San Diego County where there are no natural ground water basins are compelled to pay a very high rate for the water which they obtain from The Metropolitan Water District, and in addition to that the agencies in San Diego County have had to build very expensive surface reservoirs to store water for peaking and shortage purposes. In reality there is no basis at all for the discriminatory rate for placing water in an underground reservoir as against placing it in a surface reservoir. Metropolitan justifies its distinction by stating that there is a public interest served in replenishing the underground basins, and in preserving those basins. On the other hand, we must remember that Metropolitan has preferential rights to its water supply: each member agency is entitled to its pro-rata share of Metropolitan's total availability of water based upon the amount of money which that agency, as a member of Metropolitan, has paid to the overall agency. In this situation the local agencies which have underlying ground water basins are given a clear advantage, for they may buy water at a reduced rate and place it in the underground for a long period of hold-over storage, while those agencies which have no ground water storage must pay the higher rate for water and may, possibly one day, be limited to the amount of water to which they are entitled by reason of paid-in taxes. In this situation it is conceivable, but hardly likely, that Orange County, for example, which stores a great deal of water underground in its replenishment program, would one day say in a time of shortage that it would relinquish a part of its entitlement in Metropolitan to an agency such as those we find in San Diego County which had need of that water. More realistically the Orange County Water District would keep its water in storage and continue to take water from Metropolitan up to its full share of entitlement.

It would be much fairer if the water that was stored in these underground basins was put there by the Metropolitan Water District. In this case Metropolitan could store the water and then pump it out and, in conjunction with surface deliveries, manage the whole distribution system on a uniform, coordinated basis. This type of management would be not only for the good of the overlying owners in Orange County but for the whole community within the Metropolitan Water District that has made possible the importation of Colorado River water, and will make possible the importation of State water after 1972. And this could be accomplished by Metropolitan as simply one feature of its overall management program without in any way jeopardizing the many powers of the local agencies affected by the overall storage program.

This same principle should apply to the State Water Project. There are thousands of acres of underground storage basins along the aqueduct route, and initially at least, there will be thousands of acre feet of project water in excess of early demands. Water should be placed in underground storage by the State as available and its subsequent use should be managed in conjunction with surface transport and deliveries.

There is not time to comment on the several aspects of acquiring storage in the underground, whether it be done by condemnation or some other method. However, Metropolitan and the State should have the right to put their water that is imported underground, there manage and control it, and not be stuck with this fantastic claim of vested property rights in favor of those people who just happen to be fortunate enough to buy an acre of ground overlying a ground water basin. Now, that ought to stir up something.

REMARKS OF MAX BOOKMAN
CONSULTING ENGINEER
Bookman and Edmonston, Glendale, California

The control of pumping in a ground water basin is an essential element in the proper management of that basin. This is true not only when an agency overlying a basin attempts to conduct its own affairs, and import water to mix with the local supply. It is true in the situation mentioned by Mr. Jennings where The Metropolitan Water District might attempt to store water in a local ground water basin for the use of

member agencies outside of the local ground water basin. This could not be done without a determination of the rights of local pumpers to their pro-rata share of the local supply.

Carl Fossette, as General Manager of the Central and West Basins, spoke of the method utilized to manage the ground water resources of those areas. There is control in those basins now of pumping. As a result the sea water barriers are nearing completion so that sea water intrusion is being prevented. The local pumping is being adjusted to the native safe yield and the amount that can be replenished to the basin. What more could we have in the way of basin management? As long as we use those tools which are still subject to the jurisdiction of a court, subject to change as experience tells us whether we should take more or less pumping or retain our ground water levels at this rate or another, we have a complete means of accomplishing just that.

These things in the Central and West basins were accomplished by a stipulation of the parties, by agreement. I believe these agreements would not have been achieved but for the pressure of legal actions which brought reticent people together. Water users are always reticent to give up their rights, to take cheaper water, and they take the more expensive imported water only reluctantly and when they are forced to. I believe legal actions to determine the rights to the ground water are essential to bring about this phase of management.

The Orange County Water District has been referred to as an example of managing the local supply without litigation. Orange County still has problems in getting its share of native water from communities upstream on the Santa Ana River who are taking it before it gets to Orange County. In fact, Orange County is engaged in considerable litigation upstream. However, this does not detract from the excellent job which Howard Crooke has done within the Orange County Water District. His knowledge of people and public relations has been an excellent example of how an area can achieve within itself a certain measure of ground water management.

I want to talk about the charge that litigation is costly and time consuming. I believe attorneys are quick to understand geologic conditions, hydrologic phenomena and are able to express these phenomena in clear language, perhaps even better than the engineers themselves, who are normally poor in expressing themselves. I find the courts are able to follow the reasoning of expert witnesses if given a chance. With some exceptions to the characteristics I have

just expressed concerning attorneys, engineers, expert witnesses and judges, I am naive enough to believe that a court can pretty well cull out the differences between the good testimony and the bad and come to a reasonably sound conclusion.

The history of litigation and the time it takes is very poor. The Raymond Basin case took 13 years before it was finally concluded. The West Basin adjudication took 16 years before it was finally determined, and there was a terrific cost involved. The Orange County case against upstream entities on the Santa Ana River took over 114 days of trial, and the matters on that stream have not yet been fully resolved. The San Luis Rey Water Conservation District case versus Carlsbad took 7 years. The Santa Margarita case before the Federal courts has taken a long time, and isn't yet fully resolved. The Upper San Jacinto Reference which was referred to the Division of Water Resources in 1950 was settled in 3 years because the parties were able to understand the facts and to agree. The Tia Juana Reference, sometimes known as Allen v. California Water and Telephone Company, was 19 years in court. The case of Long Beach against San Gabriel was recently settled after 6 years, but this again was by stipulation and was never argued in court. The Central Basin adjudication, settled only a week ago, set a record, for it was filed in 1963, and within 9 months an interim agreement signed by 80% of the pumping was entered. The case of Los Angeles v. Glendale and Burbank, on the San Fernando River was filed in 1936, and hasn't been completed even yet. Only now is the Referee completing his work and hearings are still to be entertained. This isn't a very good record, and we can only say that we must determine what rights pumpers have in the local supply if we are to manage a basin. We'll always find that there are large numbers of people involved and while we may do something to facilitate and expedite these procecures, we'll always be confronted by a tremendous amount of paper work and time consuming work in handling so many parties. Furthermore, the matter of just understanding the complex situation in any ground water basin is tremendous, and one has to spend a good deal of time in coming to these conclusions in any event.

There are several suggestions that I would like to make. It has been said that we are working with covered wagon law in an atomic age. We are working with two entirely different concepts of law: one governing surface streams, and the other covering ground water. We realize the need for conjunctive operation of surface and ground water, but we still have not brought the two governing bodies of law together. Something out to be done about this.

In 1951 we passed a law in California providing that one could cease pumping the underground if he would take surface water from outside the watershed in its place. However, the law was so worded that very few people have relied on what it says. It has not succeeded as a tool in ground water management, though it was intended to do just that in the southern counties of this State. Why can't the law be amended so that more people can have confidence in it and follow it?

Another law that has not been utilized because of lack of faith in it is that provision in our Water Code which states that a preliminary injunction may be issued where there is danger of sea water intrusion. This law was passed in 1953. There is no reason why this same provision could not be extended to inland areas.

The provision in the law for making annual reports of the amount of water that has been pumped from an underground basin or diverted has not been as successful as it might have been, because it is only a reporting statute. The accuracy of those reports must still be litigated or investigated if they are to have prima facie stature in any court room.

We must think of amending our statutory law so as to speed up the determination of water rights which are so essential for basin management. We should explore the virtues of the Lis Pendens, the notification of the property itself that its water rights (those underlying it) were being attacked. We must somehow facilitate the delineation of ground water basin boundaries, because just the definition of the area involved requires a great deal of time and usually fosters a good deal of argument. The utilization of the preliminary injunction should be explored as a means of holding in check the ground water basin, while the laborious process of determining water rights is carried on. Finally, we must find some way of speeding up the accumulation of factual material.

REMARKS OF STEPHEN C. SMITH
DIRECTOR, NATURAL RESOURCES CENTER
COLORADO STATE UNIVERSITY
Fort Collins, Colorado

As an economist I am familiar with the concept developed in the early part of the 1900's to the effect that there is a social theory of the law and a social theory of property. I agree that we do have property rights in water, but they are not absolute. These rights, like other property rights, change. Certainly the property interest in land

that a man held in 1900 is different from the kind of interest he now holds in 1965. I think the same is true with respect to ground water rights. At times, we are prone to neglect this point.

Mr. Jennings brought out the point of the possible utilization of ground water basins to serve as part of the distribution system of the Metropolitan Water District for all of its members. The concept of developing an organization to provide water service over a wide area and a long span of time, has merit. Also, his comment of having the organization hold the water rights and having the power to condemn rights should be explored. The concept of reverse condemnation should also be examined.

The three questions which the Chairman has posed for us indicate that we have not today accepted the concept of integrating surface streams with ground water. We know that the integration of these two sources is essential and yet our concepts of ground water management cannot possibly integrate them under present laws. If we are to look ahead 25 to 50 years it seems to me we ought to concentrate on these items of integration and coordination. As an economist, then, I would throw out the question whether we have really accepted this concept of integrated management in our law.

The second line of inquiry might be posed like this: What are the major elements which will point to more integrated management of our surface and ground waters? Won't the increasing pressures of population and an increasing economic pressure which will increase the cost of water in the future, as well as affect the productivity of the water in the future, force integration of management? It will bring about a more equitable distribution of water as an economic base for localities, and also insure their future growth and development.

The question concerning the rights of individuals to the underground water was raised by some of the other panelists. It was proposed that perhaps these rights might be condemned. Again we return to the question of property rights. It is not a question of whether or not these are property rights -- I think they are -- but it is a question of who owns these rights and where and at what point they might best be owned -- maybe they should be held by agencies focusing on management of our resources, such as large districts. We might consider the merits of an exchange system. Perhaps the right to store water in the underground could be exchanged with a district or other public agency for a water right, or some other benefit, which is of advantage to the person surrendering the right. The question is

who needs these rights; how do they produce the highest social good; what kind of compensation is going to be paid for them? Is it monetary, or is it a guarantee of a water supply? It is this type of flexibility that we should explore to achieve a greater depth of understanding of integrated surface ground water management.

REMARKS OF DR. JOHN F. MANN, JR.
CONSULTING GEOLOGIST AND HYDROLOGIST
La Habra, California

I would like to pursue a line of thought that has been developed by the previous speakers. There appears to be a double standard in looking at surface waters or water stored on the surface, and water stored underground. Why is it that the same person who will fight for every last dollar in building, say a steel tank on the surface, will needlessly spend, perhaps millions of dollars to store imported water underground. I believe that the economic approach to storing water on the surface and storing it underground is often different in practice. To some, ground water management appears to have the same connotation as conservation -- everyone's for it. There may be a certain exhilaration when a person releases water out of a pipeline and lets it run down the river and go underground. Some people who take surface water from a pipe and run it down a well feel they are conserving water. But this is not necessarily conservation. The same economic test should be applied to water on the surface and water underground. Let us analyze the problem of keeping a ground water basin full. Ground water basins are individual things, and there may be places where, as Mr. Roll pointed out this morning, because of subsidence the maintenance of high water levels is a very important thing. Keeping a ground water basin full for the sake of keeping it full, or for the sake of saying that you have a very large reserve underground is of questionable merit. I think an underground reserve should be subjected to the same test as a surface storage reserve. If you were in any area that depended partly on natural supplies and partly on imported supplies -- which applies to many of the ground water basins in California -- you could compound possible catastrophes, and you could calculate how much water would be needed to repair an aqueduct that perhaps had been put out of service because a tunnel had failed. You can reasonably calculate how much time it will take to repair the damage, and how much water is needed. Keeping 10 million acre-feet of water underground when you only need 1 million acre-feet by compounding all possible catastrophes, may be an economic waste. Part of the problem comes from a lack of understanding, or a lack of confidence in the estimate of water stored underground. We have methods now to demonstrate capacity within

reasonable accuracy. If you've got 10 million acre-feet underground, and you need 1 million, it usually doesn't make too much difference if that 10 million is only 5 million. Why should we insist upon a safety factor of 10 or 20 in an underground basin, and yet build that steel surface storage with a safety factor of 2. Every ground water basin has different physical characteristics. Let's say the basin is second downstream, and most of its supply comes from the spill of the basin immediately upstream. It is necessary to find out how much water is available from upstream, and how much spill is required to satisfy downstream rights. We can see in the law a great deal of emerging flexibility. It started with the Raymond Basin case. Here for the first ime we had a resolution of the problem of ground water management versus legal rights. Which is the dog, and which is the tail? The ground water management scheme should be the controlling factor, and with the Raymond Basin case we started to have the dog wagging the tail. The Raymond Basin solution, although it represents only one type of problem and one type of solution, is interesting because it bears on the question of the role of the law in the future concerning ground water rights. The classic Raymond Basin solution is referred to by lawyers as the Pasadena rule. Is it <u>the</u> rule, or many rules? The Raymond Basin itself is not physically simple, and the solution there was not simply one of a great deep bucket of water apportioned to the existing pumpers on the basis of a five-year so-called prescriptive period. There are three areas in the Raymond Basin. In two areas, the Referee found an overdraft, and the pumping was cut back. In the third area no overdraft was found, and yet pumping rights were apportioned. What kind of prescription or mutual prescription is this?

Next comes the West Basin. There, using the format of the Raymond Basin, another stipulated judgment was entered, apportioning, not the safe yield, but what was left of the safe yield, because the heavy pumping in the Central Basin had reduced the underflow from east to west into the West Basin to a very low figure. I would suggest the stipulated judgment there was the rubber stamping of a physical solution assigning rights to mined ground water.

When we move to the Central Basin adjudication, there was no particular attempt to equate pumping rights to the safe yield. The central theme of this was a ground water management plan, and so I think that perhaps we have here in the Raymond Basin type of approach a solution to a great complexity of problems. Although mutual prescription in its classic sense was developed in the western unit in the Raymond Basin, the classic pattern is not the one that has been followed. A physical solution was worked out, and a broad flexibility in

the law was developed through this case. It gives us the opportunity to solve water rights in many areas that are much more complex physically than in any of the basins that have been adjudicated under this approach so far. This is very fortunate, and I can't stress enough the importance of the stipulated judgment because the legal requirements for injunction are very strict. Under a stipulated judgment, people can agree to facts which become legally true, and you really don't have to worry whether they are physically true or not. The Raymond Basin pattern, and especially the incorporated stipulated judgment, permits the optimum operation of a ground water basin through bypassing those features of the classic water law which might frustrate that optimum operation.

REMARKS OF G. EDWARD FITZGERALD, ESQ.
GIBSON, DUNN AND CRUTCHER, ATTORNEYS AT LAW
Los Angeles, California

In listening to Mr. Bookman's analysis of the past history of our litigation it does follow a rather drastic, and what we might term almost horrible history. The fact is that California water history is replete with the history of relitigating the same water streams. How many times prior to 1956 did the City of Los Angeles bring lawsuits to establish its so-called pueblo rights in the Los Angeles River. While we're attempting to simplify the problem for the future, we must examine the question in the context of our past history. We cannot simply solve the problem now and then go marching off every 20 years to relitigate our lawsuits, as we have done in most of our Southern California water litigation. Santa Ana River is another typical example. It is in litigation again. It was litigated 10 years ago, and it was litigated back in 1920. Water litigation is complex, and it is difficult, but some of its complexity is self-made, and some of it is caused by the fact that our procedural rules with which we try most of our lawsuits are not adaptable to water litigation. In water litigation one of the great aspects of the case is the time involved, and not only the time involved, but the cost involved. You can win the lawsuit, but after the 10 years of adding up bills from attorneys, engineers and others, you sometimes wonder how much you have won. I have always been amazed in the trials of most water litigation in the vast area of agreement, not that of disagreement. In most cases, the engineers, the geologists and the water engineers are in agreement as to the basic facts of the litigation. They know where the basin is; they know who lies above it; they know who pumps the water out of it. And it is only in rare instances that we end up with time-consuming bickering as to relatively minor

aspects of the litigation. It is too late in our time in history to say that we have no property right in water. Too much of our economy has been built upon it. Too many of our people depend upon it, and it provides an impractical solution to our problem to say that we simply have no property right in our water. In most instances before ground water management can be effective, we must have a determination of what those rights are, and our primary aim and goal should be to simplify the procedures by which we make those determinations, and I cannot help but think this can be done. We must derive a system that will make the litigation binding on all parties to the basin regardless of whether they are presently pumping water or not, so that we don't end up with a situation where we solve the problem now and 10 years from now we relitigate it because there are some new parties involved. We must find a system where the property right in basin water can be brought into court and is brought into court regardless of whether that land is presently producing water or not. Procedurally, we must find a way to shift the cost of litigation, and this is not an insignificant part of it. The costs of the City of San Fernando case have already exceeded half a million dollars. Most defendants are, and perhaps even most plaintiffs, while they may be willing to quibble over details if they don't have to pay for it, are not usually willing to do so if they think it's going to cost them a substantial portion of either their rights or their money. And it strikes me that we must find a method of determining the factual situation, either through the processes of the Water Resources Board or by some other means, and then ask the parties to either stipulate to those facts or litigate them at the cost of reimbursing the other parties if they happen to be wrong. The emphasis of our litigation has been in the past to allow everybody to take any position they desired, no matter how ridiculous or how absurd, and the penalty for it has been practically nil. It's time we put some teeth in to our procedural aspects of water litigation, and if we can do this we will find that lawsuits will not be unnecessarily delayed by quibbling. After all the problems, though complex, are also simple. They consist of identifying the basin, identifying the parties, and then allocating the various rights. This in its simplest context can be done because most parties to water litigation recognize that they either use the basin together or ultimately they dry it up together. Under these circumstances the engineers and lawyers sould be concentrating on means to establish a simplified procedure of determining elemental facts which our litigation can then proceed on to the basic issue of how the basin should be operated in simple fashion.

K-1

QUALITY ASPECTS OF GROUND WATER USE AND MANAGEMENT

Moderator: P. H. McGauhey
Chairman, Department of Civil Engineering
University of California, Berkeley

Albert F. Bush, Professor of Engineering, Dept. of Engineering, University of Calif., Los Angeles

Arthur J. Inerfield, Water Quality Staff Specialist, Division of Resources Planning, Calif. State Dept. of Water Resources, Sacramento

Owen R. Lunt, Professor of Plant Nutrition, Dept. of Botany and Plant Biochemistry, University of Calif., Los Angeles

J. E. McKee, Professor of Environmental Health Engineering, Calif. Institute of Technology, Pasadena

John D. Parkhurst, Chief Engineer and General Manager, County Sanitation Districts of Los Angeles County

Frank M. Stead, Chief, Division of Environmental Sanitation, Calif. State Dept. of Public Health, Berkeley

One term that we have heard repeated many times during this session is "management of ground water" and ground water basins. The term "management" has many connotations, many definitions, and yet you cannot get very far in speaking of managing a ground water basin without first defining the criterion or premise upon which management is to take place. One of the primary criteria, of course, is the quality of the water itself, and unless we have a criteria of water quality with which to work, management itself can be quite meaningless.

This afternoon our first session deals with the subject of water quality from ground water basins. In California, the majority of the population literally lives over the leaky roofs of its own water supply, and the prevention of pollution, the upgrading of water quality, the prevention of sea water intrusion and many of the other factors which enter into and affect ground water quality, are of primary importance to us. To lead this afternoon's panel, Prof. McGauhey of the University of California, who has had a long career in the field of sanitary engineering, and is currently Director of the Sanitary Engineering Research Laboratory of the University, will lead the discussion. I will turn the meeting over to Prof. McGauhey at this time.

McGauhey:

Thank you, Mr. Chairman. Ladies and gentlemen: I am glad to be here and to welcome you to the discussions that we are going to initiate through this panel. Continuing the precedent set this morning by Dr. Hall, this panel is not going to present any prepared speeches. Instead I am

going to try to initiate rather promptly a discussion of this matter of the quality aspect of ground water management. To launch the discussion I am going to take the privilege of first addressing a few remarks to the audience, to describe the nature and objectives of our panel. We have assembled here a panel of what I call "old pros" in the water quality field, to put on an unscheduled and unrehearsed performance. Identifying them: at the far end of the table is Prof. Jack McKee, next John Parkhurst, next Frank Stead, next Artur Inerfield, next Prof. Albert Bush, and at this end of the table, Prof. Owen Lunt. I shall not take time to list all the qualifications of these distinguished panel members. They all graduated from one university or another, by one device or another. For the purpose of this panel discussion, they are all experts on all aspects of the subject. The printed program which you have before you lists their current titles which were earned presumably in recognition of this expertness. Represented on the panel are those concerned with the discovery and exploration of the ways in which water changes in quality as it percolates downward through the soil or is translated laterally during storage underground; those concerned with the basic methods of getting water into the ground, changing its quality, and managing its use; those concerned with developing the criteria or standards by which we judge the quality of ground water, by which we relate quality to use, and by which we establish the goals of technical processes and other facets of management. We have those concerned with the practical problems of ground water management and development; with the quality needs for water to be used by man; with the quality needs for the water to be used by agriculture; and with almost any other aspect of water quality that you might imagine.

I would address a few remarks to the panel itself. I hope to act here in the role of a master of ceremonies. With questions and comments I shall endeavor to lead the panel in a discussion which will be directed to bringing out the role of research, of regulatory controls, of quality needs of beneficial uses, and of practical consideration in getting water into the ground, and getting it out again in such a fashion as to maintain its quality at an optimum level. Above all things, I would hope that we shall deal with ideas rather than with technical details; with concepts and their significance.

To begin the discussion I am going to call on John Parkhurst. John has been responsible for a major pioneering project in waste water reclamation which involves putting water into the ground. Waste water, we may presume, has a considerably lower quality than water imported for ground water recharge, hence a consideration of its ground water implications is a good place to begin our discussions. I would therefore address two questions, first to Mr. Parkhurst, and later to others in the panel. (1) How do ground water quality considerations affect what you are doing to waste water and with waste water? Question two--related and, perhaps more important--is: How does your activity in waste water reclamation affect the quality of the ground water?

Parkhurst:

Thank you, Prof. McGauhey. These two questions are of course very thoroughly interrelated. First of all, the Whittier Narrows Water Reclamation Plant which is the prime source of reclaimed water in the Sanitation District's program at this time, is located on the Rio Hondo

River very close to the intersection of the Rosemead Boulevard and San Gabriel Boulevard in the reservoir area of the Whittier Narrows Dam. The water from this plant, after receiving secondary treatment and then tertiary treatment for removal of ABS, is percolated into the ground waters of the central and west basin of the County of Los Angeles, and ultimately is being used along with the other ground waters for unrestricted use. Now, of course, the concern is first for the quality of existing water that has been in the basin for a long time. That is, the effect that the reclaimed water may have in the degradation of the water that is already there. So at the very start we have a concern for the quality of the water into which we're putting the reclaimed water, and therefore we must be concerned with the quality of water which we are putting into it. So these two are very, very closely related in our care; and any waste water reclamation program must be planned, and certainly be carried out, in such a manner that it will not materially reduce the quality of water that is in the basin into which it's being discharged.

McGauhey:

John, when you establish such a program in the first place, do you decide which processes you are going to use on the basis of ground water quality objectives?

Parkhurst:

Knowing the approximate quality of the existing basin in which we would be discharging, we actually surveyed and very carefully determined that the reclamation and discharge of reclaimed waste water into this basin would not result in a deterioration of the quality of the water.

McGauhey:

Thank you, I know that since you have been in operation you have amassed some evidence to support many conclusions that you might draw concerning the effect on ground water quality, and I believe you have had Prof. McKee to assist in this work. Jack might wish to tell us a bit about what evidence has accrued to indicate that the ground water quality is being protected; and in what way it is being protected.

McKee:

Thank you, Mac. First of all, several points should be made with respect to the waste water at Whittier Narrows. The total dissolved solids of the waste water and the mineral constituents in general of the reclaimed water at Whittier Narrows are better than the Colorado River water, so we have to recognize that insofar as total dissolved solids, calcium, sodium, and various minerals of this sort are concerned, there is no substantial difference between the waste water and the Colorado River water. Colorado River water has been spread at the Whittier Narrows area for several years, several hundred thousand acre-feet have been spread. Actually the water discharged from the Whittier Narrows Water Reclamation Plant is about 15,000 acre-feet a year. So you see this is a relatively small proportion of the total amount of water that is spread.

The second point I want to stress then is that there is a considerable dilution of the waste water either by the natural waters or by Colorado River water. That ratio is 8 or 9 to 1. The third point I want to get across is that we have monitored the wells in the vicinity of the spreading basins which are operated by L.A. County Flood Control District, and to date we have found no deterioration of the quality of those wells as a result of the spreading operation. I might say that probably the best tracer that we have for this purpose is the detergent ABS and we've been watching that very carefully. There's no evidence of any deterioration and later on I hope to show evidence which will indicate that there will be no deterioration even in the future.

McGauhey:

Jack, I presume you are speaking in terms of mineral quality when you say the recharged water is better quality than the Colorado River water.

McKee:

Yes, I was.

McGauhey:

But what about the nutrients and the biological quality of this water?

McKee:

Well, from a biological point of view, I may say that the water is heavily chlorinated when it leaves the Whittier Narrows Water Reclamation Plant. We find that the water at the point of spreading on a little test spreading basin that we have been operating is almost as good as drinking water quality as far as the coliform organisms are concerned. A typical count would be perhaps 100 or 200 coliforms per ml at the point of spreading, and I'm sure that the Sanitation Districts could make it equal to drinking water quality if there was any necessity to do so. The coliforms, that is the fecal coliforms, are removed very effectively in percolation through the soil, but in our experiments we found something very rare. The coliforms at the surface and in the surface water averaged 190 per 100 ml, but down at the 2-ft pan where we collect other water samples the coliforms ran 10,000 per 100 ml, and at the 8-ft pan they were 20,000 per 100 ml. Now those are coliform organisms and they created a frightening aspect until we looked into the situation in more detail. Then we found that what we were doing was growing soil bacteria, the aerobacter aerogenes type of soil bacteria and not the fecal coliforms. When we ran the test for fecal coliforms we found that they were in effect virtually absent after a few feet of percolation through the soil. We also ran fecal streptococci and found almost complete removal of the fecal streps in percolation through the soil, so that from a viewpoint of biological quality, there is no need to worry.

McGauhey:

I wanted to ask, John, is the reclaimed water going back into a domestic water supply?

Parkhurst:

Do you mean, is a pipe carrying the water, or do you mean is the water going into a ground water basin from which a domestic supply is being obtained?

McGauhey:

I mean a basin from which a domestic water supply is being obtained.

Parkhurst: The answer is very definitely yes.

Inerfield:

Let me make this question! A sewage or at least a waste water contains two kinds of substances, those about which we know something and those about which we don't know too much. Those we don't know anything about we lump together and determine their amount by measuring the BOD's and the COD's.

Now in view of the fact that there are constituents of sewage about which we know so little, can we be really certain that what we're doing when we recharge a domestic water, or least a ground water basin which may provide us with domestic water? Do we really know we're taking all the precautions necessary to make sure that this will be a safe and wholesome and potable water?

McGauhey:

For a partial answer to that, maybe we ought to call upon Frank Stead. Frank, from the point of view of public health, are you satisfied with the quality of the ground water that is resulting in this particular situation?

Stead:

Since most of us here represent the area of environmental control in the engineering view, and we don't have too many sociologists and medical people present, let's take our hair down a little bit.

Of course, we don't know. This life is a gamble. The environmental business is an experiment and you can experiment responsibly or irresponsibly. I believe that the case in point is a responsible experimentation but it still is an experiment and the gamble may turn out successfully and it may not. In fact, the Riverside epidemic, salmonellosis, indicates that there's always some surprise in store in this experimental business. Now the way we proceed is not very glamorous. It doesn't really stretch the imagination and fire up zeal as a pioneering venture. Let me give you an illustration. When spreading was first considered in Los Angeles County, our Department was asked for a position, and instead of starting from first principles, the actual physics and mechanics and biochemical balances and equilibrium that are in the soil systems, we took this very simple kind of a step of approving a responsible experiment.

The outbreak of cholera at Hamburg, Germany several hundred years ago brought to light the startling fact that the citizens of Altoona got their water supply from the same river, but with slow sand filtration,

those citizens escaped the cholera epidemic. The citizens of Hamburg who took the water directly from the river heavily contaminated with sewage were stricken. So empirically it was discovered that the upper few inches of the soil mantle of the earth is a real meaningful environmental barrier to the travel of pathogens. In our case, we said to the County Sanitation District back in 1946, we don't know about spreading; so, to begin with, put it on the surface and we'll have this soil mantle working for us. The effect of this soil mantle was confirmed by work here in Azusa and at Richmond, California. We advance empirically but, I believe, responsibly, and this system carries no guarantee that there will never be a failure. We hope there will never be a catastrophic failure, but if we are to wait until we have enough fundamental information to predict the effect of the Whittier Narrows venture without any question of certainty of the information, then we wouldn't receive the benefits.

You might ask why a health department looks with favor on this type of breakout into new untried methods. In addition to the obvious factors of conservation of a resource, let me just suggest this thing to you that perhaps you haven't thought about. Suppose you had to live in a world divided into two zones--patches of the geography all shaded either green or red. The green zones are safe zones; in the case of water, these are environments in which the water is safe. The red zones are danger zones; this is the segment of the water resource that is thought of as sewage and must be fenced off in some way. An illustration of this principle is a water pollution district dedicating a zone to waste disposal; this is a red zone. Reclamation, for the first time, permits us to have the whole state green. If you were the health department, the attractiveness of this idea and the long peaceful nights of sleep that would then accrue to you would be very appealing.

McGauhey:

There's something here that doesn't quite jibe. Frank has just said that on the basis of experiments in which, of course, I was also involved, we concluded we were getting pathogens out in the top two inches or so of the soil. Prof. McKee has just described to us a very flourishing bacterial population at a deeper depth than at his sampling wells. Jack,what is the answer here? Is there a discrepancy?

McKee:

No, there's no discrepancy.

McGauhey:

Just how do the bacteria get down there?

McKee:

This was an agricultural soil that we started with, very tight soil, incidentally, with a low infiltration capacity, and the soil was naturally teeming with the soil organisms such as aerobacter aerogenes. We gave them almost an ideal environment in which to grow. They were

alternately wetted and dried, or aerated, and they got lots of nutrients from the waste water because, as Art Inerfield pointed out, there's still organic matter in the waste water, it's not just all mineral matter.

McGauhey:

This is the point I wanted to bring out, that the bacteria were down there and we just sent them down some lunch.

Parkhurst:

I think that I should answer Art's question at least in part. First of all, I think that I agree very much with Mr. Stead. Inasmuch as we now have a situation in which we are all at least acting in the open, we are moving ahead in the field in which we're all aware of what we are doing, and we are taking all the necessary safeguards that we can possibly take. We believe that the risks which are involved are probably less than the other risks that are taken every day throughout the country in obtaining our water supplies. The reason I make that statement is that as an example, the state is bringing water down to Southern California under the California Water Plan. This water is coming out of the region of the Sacramento River and will be treated here with the standard water treatment plants, presumably, or it will be put back into the underground. But at the time it reaches Southern California it probably contains a considerable quantity of sewage effluent which originated in the Sacramento Valley. It will contain a large portion of the waste water from the City of Sacramento, and perhaps, Marysville. It will contain some of the chemical agents which are used in the valley for control of weeds, and insects, for instance, in the rice fields. It will contain surface runoff which will have some of these various quality depressing factors. But this is a water supply that we are forced to live with. This is the best that we have to bring down to Southern California.

The same thing is true in other parts of the country. Many cities are using water out of the Great Lakes, which is every day receiving industrial discharges. Chemical wastes are going into it. Raw sewage is going into it. And only a few thousand feet away from these discharges perhaps there is a fresh water intake. Some of these intakes are getting so badly clogged, with the algae and so forth, that they're having trouble getting the water in. I think you should face up--and we certainly are--to the relative risks which are involved. We've got to obtain water. Everybody knows this. We have at Whittier Narrows a process that we have every reason to believe is safe and we have, after almost three years of operation, had nothing which would disturb this belief.

The United States Public Health Service of Cincinnati is even more progressive in this field than we are. They are actually looking at the direct reuse of waste water in the future. Of course we do not yet have a process that will give us water which can be put directly back into the domestic supply. But some day, I venture to say, we will have. How many years in the future this will be I do not know. At the present time we have the extra additional safeguard of percolation through the world's best slow sand filter before it goes back into the

water basin from which the domestic supply is being obtained. So I don't think that we are taking too much risk in what we are doing, although I agree with Mr. Stead that there is a certain calculated risk even today. We always have to face this.

McGauhey:

John, I'd like to pick up something that you just said, and that Art Inerfield perhaps implied. What are the reasons that have been advanced for not taking water and using it directly above ground? Mostly they have been these unknown factors to which Art referred without identifying. Prominent among the list of unknowns are the viruses. Whenever we start talking about the unknowns we generally want to know what becomes of the virus; and I may recall that back in the early days of research in the ground water recharge, which is only 15 years ago, one of the reasons for not putting water underground was that bacteria might travel along very freely. The results of some of the research have been mentioned by Mr. Stead when he said it was discovered that bacterial travel was not an important factor. Some of us who were vastly enthusiastic then as now about ground water recharge as a method for conserving water said, "Let's be about it" but others argued, "But what do you know about virus?" Well, we didn't know anything about virus, so obviously we couldn't move. By now I think that this particular subject of virus has been clarified some and I believe that Prof. Bush has some information that he might at this point introduce to bring that facet into the discussion.

Bush:

Thank you, Mac. I would like to say a word about waste water reclamation and the underground recharging that can be done with this. First, in support of what Mr. Parkhurst and Mr. Stead have just said, I think that we should all reflect for a minute on the 50 years of progress in sanitation that we've made, because many of us remember the times when we lived with cesspools and septic tanks that were recharging the underground water basins very directly. I think that there is very little doubt that epidemiological evidence supports the fact that these devices did not really become conducive to waterborne epidemics. In fact, the use of septic tanks was a pretty well established sanitation step. Now that we've taken the water out of a lot of septic tanks and cesspools and discharged it into the ocean, I think that we've almost made a step backwards in replenishment of the underground water basins. So what we're talking about today, I think, is reversing this cycle and putting the waste waters back underground. Two things have happened that have led us to some concern in this. First, the use of synthetic detergents, and I think this one has been pretty well brought under research scrutiny; and second, the question of virus, not because of virus epidemics that were produced but because of the question of what happens if virus does travel with recharged water. In connection with this subject here at UCLA, in cooperation with the Medical School, we had the opportunity to do some experimenting with our water reclamation system which we have on the roof of the Engineering Building. We inoculated this system with coccaceae virus in very, very high dosages, much higher than you would get even in cases of an epidemic in a city where these might be going into the sewer. We then studied the behavior of the

system in removing this virus. It was of interest to us that when we operated with a very, very low sludge index, providing a very light activated sludge block, these viruses did go through the system and could be retrieved in the final effluent. However, when we changed this about and brought the activated sludge index up to normal levels or above normal levels, we found that we got no measurable amounts of virus going through.

I might say that virus work is difficult. I don't recommend that anyone for routine investigations start growing mice colonies by the thousands as we had to. But in a research situation you can maintain animal colonies and you can make the tests and you can satisfy yourself that there is removal going on in the systems that are being used currently to treat the water before it goes into the underground basins. So I think as a result of this study--which has been published--we have a much greater appreciation of the removal mechanism and the fact that we now can under proper treatment conditions remove the virus from the water and then percolate the water into the soil with some assurance that it will not be producing disease. We have, of course, done this with only one form of virus--but since virus are very small organisms, much smaller than the bacteria--there seems to be some evidence that they act similarly in their ability to penetrate into the soil and into the ground. So I would say as a result of this I certainly have a great deal more confidence in our recharged water when we actually treat wastes first with activated sludge processes before we discharge them into the water.

Regarding the point that was suggested a minute ago, that we may some day use sewage from up north, I think that we in the south fully expect that this water will not be raw sewage but the direct effluent from proper treatment facilities and if that is the case then the possibility of virus disease being transmitted by this mechanism is certainly far different than if we were taking raw sewage.

McGauhey:

Frank, do you wish to comment?

Stead:

I think we're all guilty of blind spots. It's easier to see the other guy's limitations than our own. But whoever posed the question of virus in connection with replenishment of ground water with reclaimed sewage asked the wrong question. The greatest likelihood of a short-circuiting of virus into the human system would be by the discharge of treated sewage into a stream system with no travel through the soil involved. Now the reason that likelihood doesn't have sex appeal was that it has been going on for 50 years and nobody could get excited about it even though it was a real risk. The reason we became interested in the Santee experiment was not the safety of ground water at all. That has been demonstrated for the past 50 years by the millions of gallons per day of septic-tank effluent which have entered the ground below the top few inches, not having the advantage of this top part of the mantle at all. What we were interested in is something new--direct reuse on the surface of the ground of water reclaimed from sewage for a variety of uses

involving irrigation, recreation, and direct recycling into the domestic water systems. This is the new direct short circuit link that we are exploring, not the question of viruses either in the standard system of disposal treated sewage by dilution or in the methods of land disposal that are going on in California; not a very exciting question to ask. It had already been answered.

McGauhey:

There's one other aspect that I think we ought to inquire into before we open up the discussion to the audience. Thus far we have talked here only of water that we ourselves are going to consume. Obviously we know that control of water quality, both ground water and surface water, is related to a great many other beneficial uses. Dr. Lunt has had a great deal of experience in the quality of water needed by agriculture, and I would like to inquire of him if there are any implications that he sees in this particular water reclamation we are talking about, that would limit the use of water for agricultural purposes. By this I mean not only irrigation but for consumption by farm animals or any other aspect that he thinks ought to be called to our attention.

Lunt:

Thank you, Mac. Perhaps I should comment just a bit about the quality characteristics that are of interest in agriculture. The total salt content is a characteristic of major consideration. Agricultural crops vary a great deal in the tolerance which they display to dissolved salts in the water, but there is a limit at which water becomes essentially useless. Hence the total amount of salts that eventually get into the water supply is certainly a matter of concern regarding its use in agriculture. Another broad area that concerns quality is the ratios and kinds of salts that exist in the water supply. Soils have to be in a state of aggregation. This is, all soils except very sandy soils, in order for water to penetrate at all. If a soil were completely dispersed and consisted of a single grain particle size, it would be completely impermeable to water. Now the structure that soils develop is a dynamic thing and very definitely tied in to the quality of water with which the soils are in equilibrium. The amount of sodium that is adsorbed on the clay surfaces affects the properties of the clays and of the aggregates, if the level of sodium is excessively high, then the aggregates become unstable, they disperse and infiltration of water becomes impaired. This can lead to a whole series of difficult management problems, and so the relative amounts of particularly sodium and the divalent ions are important as they affect the structural stability of soils. Also, the total salt content of the water affects this property, so we don't have a fixed criterion which is permissible in terms of, say, the sodium to calcium and magnesium amounts. We have been using a property we call the SAR, the sodium absorption ratio. As applied to irrigation water, this is simply the ratio of sodium to the square root of one-half the sum of calcium plus magnesium. Now this particular property, as I say, influences stability, but the total amount of dissolved solids also influences structural stability. The higher the salt content the higher the level of this SAR that can be tolerated. So we have salt content _per se_ and the water characteristics which affect structural stability in soil as

two important characteristics; and finally, the toxicity of constituents that may exist in the water itself. Certain constituents, such as boron, which may be present in very small concentrations, can be quite toxic to plants. These are the broad considerations regarding application to agriculture.

There has been considerable interest in recent years in the direct use of relatively raw sewage water for applications in agriculture. I think the cautious exploration of the use of such water is fairly encouraging. I know of two cases where this is being applied to golf courses and I think with relatively good success. My understanding is that the concentration of detergents happens to be usually a problem of greater concern than these other characteristics which I have described. But it strikes me that this is very definitely a potential use of water which probably in many cases would be quite feasible; in fact, I think in some cases it might be advantageous because of the amount of fertilizer minerals that may be present in the water. It does represent an opportunity to use water at a fairly low cost; that is, in relation to the reclamation cost by other means.

McGauhey:

Could we upset the original question a little and ask you, Dr. Lunt, and any other member of the panel if you foresee that, in the interest of ground water quality maintenance, it may be necessary to treat agricultural return waters themselves to change their salinity before we put them underground. Ultimately we are concerned with quality of ground water.

Lunt:

This is a difficult and complex question and one in which we've been engaged in a national dispute recently. As I indicated, waters do ultimately reach a point as a result of their agricultural use where they become essentially useless. This point is not at all well-defined because so much depends upon management situations that crop from the soil.

McGauhey:

By "useless" you mean for further crop growing?

Lunt:

Yes, for further crop growing.

McGauhey:

Are they also useless for recharge underground again, and if so, how are we going to prevent it? I'd like to ask Mr. Inerfield to comment on this question.

Inerfield:

Well, I think one of the approaches which is favored by agriculture where drainage waters become of very low value in agriculture, is to bypass waters into some drain to the ocean rather than contaminate existing water that is of reasonable quality.

This is not the kind of a question there's an answer to. The economic and engineering problems involved are not simple.

McGauhey:

Well, Inerfield's organization has, of course, the overall concern to manage ground water and surface water simultaneously or conjunctively, and he might wish to comment further on ground water quality before we call on the audience.

Inerfield:

I think that the matter of water quality is a prime element in this whole matter of management. It has been mentioned that there comes a point when sodium is too high; when something happens to the use of water onto soil. One of the things I think we have to know (and I'd like to ask if we do know this) is what would be the value of reducing the sodium by, say, 10 per cent? In other words, what are the water quality criteria that can be used in evaluating irrigation water which will give us something to hang onto when we're trying to compare alternative supplies, whether or not we should introduce a desalinized water into a ground water basin so as to reduce some of these constituents? What do we know about the value of reducing concentrations of salts within the range of usable water? If we don't know much, what are we doing about trying to find out?

McGauhey:

Art, there's a point that might be thrown in at this particular time. We have, as you know, an office of saline water, which has a great deal of money to spend in its program of desalinization of water. It seems to me that we are giving too much attention to getting water out of the ocean. Some of us are advocating that at the federal level they ought to expand the whole concept of this office to include the obtaining of water from all sources, that is, to get water out of agricultural returned waters or urban waste waters, to get water relieved of its salinity before it gets clear down to the lowest elevation we have to deal with. And it may well be that Art is putting his finger on something we're going to have to go after at a policy level.

Well, I think we've got the panel warmed up enough now that we might call upon the audience to participate in the discussion. We have some floor microphones and I've been instructed by our general chairman that since these discussions are to be recorded we would like to know who made the statement.

Prof. Richard Orcutt, University of Nevada:

I haven't heard much said about the possibility of injecting waste water. I know there is some work being done around the country, particularly in the Orange County area, and I'd like to have somebody comment on this.

McGauhey:

Do you want to know about the quality implications of this approach, is that your question? We have been concerned here primarily

with the quality of the ground water and how to manage it, and are you trying to get at the quality implications of that type of a scheme for putting water in the ground?

Prof. Orcutt:

That's correct. We have discussed spreading, I wanted to know what implications are of injection rather than spreading.

McGauhey:

Who wants to have a try at answering this question?

Stead:

I may lead off by saying that when you directly inject, rather than spread, as a means of replenishment, you have deprived yourself of a time-tested link in the chain of barriers which prevents the spread of pathogens. You therefore have to carefully explore what happens when your starting point is not the surface of the ground but is the aquifer itself. Now, this presents a problem of no small proportions. To refer again to the Orange County experience, a one-year-long intensified effort is being made to answer some of these questions. Whether they will all be answered at the end of this year or whether some new ones will be posed, as the original ones were answered, remains to be seen. I don't think we've finished with the principle that Jack McKee mentioned. When you set up a new environment and it seeds itself, as you must assume it will, a new steady state is achieved never before seen in the natural condition. I think we have an obligation not merely to apply the old parameters--is it in control or out of control--but to recognize that we have a whole new, unknown situation and make a pretty rigorous study of it. So from the quality point of view we are assuming in the State Health Department that the initial injections must involve water of a quality that we're satisfied to accept from the aquifer itself. Sooner or later, we should be able to give the aquifer credit for some ability to continue improved water quality. At the outset, however, we have to impose what may ultimately prove to be an unreasonably severe restriction. So the real questions are practical questions. What burden can you put on the formation to do part of the job for you as is now done by the soil mantle? This is the question as I see it.

McGauhey:

I believe Jack McKee wanted to speak on that point.

McKee:

In conjunction with the L.A. County Flood Control District we performed some rather intensive studies at Hyperion on the injection of the Hyperion effluent into a confined aquifer. There the aquifer had been completely saline, but after several years of operation it was fresh out for a distance of four, five, or six hundred feet. The problems encountered were partly physical and partly chemical. From a physical point of view, if you are injecting into a confined aquifer through a recharge well it's necessary to give the water a very high degree of filtration before you put it into the aquifer, otherwise it will plug up very quickly around the well. We computed, for example, at Hyperion

that the rate at which water was passing into the soil in the perforated part of the well, was about the same as in a rapid sand filter, namely, about two gallons per minute per square foot. And if a rapid sand filter clogs in 24 to 72 hours under normal operations you can expect the aquifer to clog quickly. Of course, we didn't give it a chance to do so, because we filtered the water through a sand filter or through a diatomite filter before injecting it. So it is possible physically to get the water into the ground. This well ran for a year, and accepted the water just as well as it accepted the tap water, which was Metropolitan District Water in that particular location.

With respect to chemical quality, the major consideration is the fact that the water goes anaerobic within about five to ten feet from the injection site. The water contained about two or three parts per million of dissolved oxygen when it was injected, but just 20 feet away it was anaerobic. Fortunately, even 300 feet away we found no evidence of sulfate-splitting organisms. In other words, we did not get any H_2S out and we didn't get any diminution in sulfates. However, to find out what would happen to nitrates, we slugged the water with nitrates when we put it in, and 20 feet away there were no nitrates. Those nitrates had been completely denitrified, supposedly into nitrogen gas. So anybody who is worried about nitrates can be sure that if you inject in this fashion you're not going to have to worry about nitrates in an anaerobic environment.

With regard to ABS, we found no change in ABS going through this confined aquifer because it was an anaerobic system. On the other hand, at Whittier Narrows, where we used the soil mantle and the aerobic environment, loading the basin every day incidentally to about two feet of water and letting it dry out very quickly, so that the soil was free to aerate for at least 12 hours a day, we had a completely aerobic environment and we got 100 per cent biodegradation of the ABS. If anybody tells you that ABS is hard, completely hard, and is not biologically degradable, I can say "hokum." We have very excellent proof that you can get 100 per cent biodegradation of ABS by intermittent percolation through the soil mantle.

McGauhey:

Thanks, Jack. Prof. Orcutt, I trust this answers your question. Both of the speakers have noted that when you put water through the biologically active zone in the soil, you are putting it through one more treatment process that isn't normally found underground. However, Prof. McKee has just called attention to some circumstances under which changes are made.

McKee:

I might mention briefly that there is a project now in Nassau County, New York, which is intended to inject, as I recall, one to three million gallons of water per day. It is going to be a very interesting project to watch. We are all much interested in how it turns out.

Member of Audience:

I'd like to know how we can attempt to educate the public to actually using reclaimed sewage water. It appears now that we're able to reclaim sewage water at low cost so it can be used after minimum filtration, it seems to be a psychological problem with the public. They don't want to do it. They've done it in Kansas where they've no other source of water but in normal situations you have to fool them or else they are not going to use reclaimed water. How can we really educate the public to accept what can in reality be a new source of water?

McGauhey:

This is one of the beauties of the ground water system. You put reclaimed water into the ground and nobody can identify it thereafter.

Perhaps Stead and others here wish to speak to your question.

Stead:

During the lunch hour, some of us were discussing this subject. You can produce, if you're skillful enough, any reaction or response you wish, for the first year at least, on the part of the public to an idea. You can accomplish a new development without any reaction if you're fortunate enough to do it covertly. For example, the institution of chlorination in water works practice was so accomplished without anybody asking a question, but when fluoridation was proposed and the question was posed, "You don't want to drink rat poison"--you all know the answer. There is no such thing as a natural repugnance on the part of the general public to a logical or rational idea and it doesn't need to be sugar-coated. At Santee, we're in the last stage of a public swimming experiment in water which is 100 per cent reclaimed from sewage. This is reclaimed water flowing through a basin to accomplish a human bioassay, both psychologically and physiologically. The kids line up for two hours in the sun waiting to get in, and they all know what it is. This community glows with pride over the fact that they're leading the parade, almost, in this country. As to the art of presenting the question in a manner in which the public can respond without too much leading one way or another, this is an area in which, in general, engineers are woefully inadequate. Just in gaining public opinion on any question, and our Department has embarked on many of these ventures, the average disciplines know nothing about interrogation to get a real answer to an issue. You and I in this room don't know how to ask an unloaded question, but I believe that the response of the public to a properly presented issue is something you don't have to worry about as being any part of the barrier to progress in this area.

McGauhey:

You made an interesting point there, Frank, that if you stand two hours in the sun it changes your point of view.

McKee wants to make a comment.

McKee:

With regard to public relations, the problem is not going to be apathy on the part of the public or resentment or opposition on the part of the public. I think the public can be very well informed about this matter. The problem we have to worry about is that some so-called "water experts" and consultants go around preaching against waste water reclamation because of political and economic reasons. The ones that I get mad about are the people who should know better. There are some in this audience who have preached against waste water reclamation because of their own selfish interests.

Member of Audience:

So far we've been talking about reclaimed water as a possible source of contamination of ground water basins, and from what I understand it's probably better than what we're using from other sources. I'm wondering, has any consideration been given to other possible sources of pollutants for the ground water basin? Such as refuse disposal dumps, and things of that type, that will provide contamination through natural percolation of rain water.

McGauhey:

There is of course a great deal of attention being given, particularly in Southern California, to the effect on ground water of the disposal of wastes of all kinds on land. Does any other member of the panel wish to speak to that?

Parkhurst:

The sanitation districts operate five landfills in Los Angeles County in which we're disposing of about 10,000 tons of refuse a day. Some of this is refuse containing garbage. We also have a lot of industrial waste. I might say that the Water Pollution Control Board is very careful about permits issued for this purpose. They survey the site in conjunction with the Water Resources Agency, the Health Department. Before we can use one of these landfills they make an investigation to determine that the disposition of the refuse will be in such a manner and so located that it will not be in contact with the ground water; and that there will be no leaching that can get into the ground water. Now this is a very important subject and there's a lot of research being done on it, and as you know, there's a lot of abandoned gravel pits in Los Angeles County that could be literally used for large sanitary landfills. However, because of this particular problem there's a great deal of caution being given to moving ahead and using these sites unless they are above the historic ground water and will be so operated that the ground water basin and the ground water of course will not suffer. I would like to add that there's a lot of work going on, in the matter of the effect of various pollutants on ground waters--oil field wastes and other pollutants--but the point I wanted to make was that in the management of ground water basins you've got to consider all of the inputs; in other words, it's just more than how much water gets put in and how much water gets taken out, but what else you're putting in. So this gets back to the point I tried to raise before: When you alter or change the quality of water, even though you have maybe only to a very minor degree affected the

volume of the water, you sustain some kind of an ecomomic loss. I think that this also has to be considered, and when the people come up with these economic models for ground water basins--these computers turning the lights on and off at 100 miles an hour--part of the input has to be to the drainage out of these garbage dumps, the seepage out of oil field wastes, and all of these various things which change the economic value of that water as a water resources.

Mr. Krieger:

I'd like to ask the panel what they think about the administrative techniques of establishing water quality standards, and perhaps even more important, the legal means of enforcing those standards.

McGauhey:

That's a very interesting question, and we have some standards people here on the panel. Mr. Stead?

Stead:

I think our present methods are obsolete. I would suggest that each of you acquire as soon as it is available, a copy of the report of Aerojet General Corporation on a waste management system for California, for these two reasons. First, it indicates that before any waste management can even be thought about on a region-wide basis, step No. 1 is to enunciate quality standards and equate them to real rather than imaginary effects on society; and second, to give in some currency a worth value to the effects, so that the thing that Art Inerfield talked about--an economic judgment--can be made. Before Jack McKee makes a speech with which I am very familiar and with which I agree let me admit that there's a lot of mumbo-jumbo and a lot of worshipping of sacred cows in the present standards. Part of the reason for this is that if you know a little about a subject it's well to deviate from the present status with a considerable degree of caution, but I believe when a standard is obsolete that we cannot much longer stick with this slow departure from 1910 standards.

McGauhey:

Jack, since your name has been taken in vain, maybe you want to defend yourself here.

McKee:

Well Mac, you will recall I said earlier today I didn't want to get into any discussion of standards and criteria. I am a great believer in criteria. A criterion, in my definition, is that by which something is judged. A standard is generally a rule established by authority and oftentimes we have many standards that cannot be supported by criteria, and in fact, in many instances administrative agencies are very anxious to have standards because they're excellent crutches to help them get their job done. I have no objection to a standard as long as there is some scientific support for it. But I hate to see standards that are arbitrarily set and then rigorously enforced.

Inerfield:

There's an important aspect of this matter of standards--criteria. I don't want to use the word standard because I don't know what it means either.

I support the idea of reclamation of waste. I think that this is a real resource that must be put to a beneficial use. But I don't want to go swimming in sewage and I don't want my kids to go swimming in sewage. I don't mind swimming in a water supply, so to speak. Somewhere along the line a determination has to be made. When has sewage become a water supply? And I think that you can't avoid the concept of criteria when you try to make this value judgment and we don't want to run to Frank Stead all the time and ask him, "Is this sewage?" This is a water supply because my kids want to go swimming. We have to set this forth in a way that people understand, and certainly the administrative agencies understand.

Stanley Lagerloff:

I rise somewhat in defense of myself. I think the reference Mr. McKee made probably included me as to those who oppose waste water reclamation for whatever motives there may be. I am involved primarily in this area, in the urban use, or domestic use of reclaimed sewage, and particularly that involved with the reclamation plant now going on in Whittier Narrows.

I think Mr. Inerfield has generally touched on the subject but I might comment on this point. The impression that I get here is that we are asking how we can get people to accept waste water as part of their water supply, hardly offering them a choice as to whether they want to accept waste water at the price offered as compared to, shall we say, alternatives of supply that may be a higher price. I think there is also another consideration that has been overlooked. It relates to what is discussed here as the gamble involved in the use of waste water, reclaimed waste water (a euphemism for sewage), for ground water recharge. Assume that your gamble doesn't pay off, that reclaimed waste water is shown by further tests and further studies to contain pollutants and contaminants that will not be eliminated by natural sand filtration or natural filtration through the soil, what is then the cost that you're going to pay for losing this experiment? I think some of the cost will be the cost of treatment to the purveyor; and I represent purveyors in the area that would be suffering this problem. There is the additional cost of liability exposure--I don't know what the liability exposure--I don't know what the liability exposure might be--but there is that cost to the purveyor. I don't know that anyone has sued anyone in the City of Riverside, or the City of Riverside itself with respect to its current problem with salmonella. But in any event, these are economic aspects of the use of reclaimed waste water for recharge which have not been discussed here and which I think are pertinent to this discussion and of major consideration.

McGauhey:

I think Mr. Inerfield has generally touched on the subject but I might comment on this point. Roger Revelle once said that this earth

is like a space ship and that all the residues that we generate from the use of our resources are going to have to go along with us. Now when we come to treat waste water, or try to get rid of waste water, the only thing we have been able to do is to sequester the waste to the ship's stores after changing its characteristics a little bit. There's only one or two things we can do with it. We can sequester it in the fresh water resource, or we can transport it to the ultimate sink of the ocean. There's no way to avoid putting it into the water resource, either after some treatment or before some treatment. When this is done you have added the increment of sewage or the increment of waste and you cannot get away from it.

Now to get down to the details of your question as to who's going to pay for mistakes, and has anyone suffered from liability or failed to recover from making a mistake. I would like to have the panel speak to this point.

Parkhurst:

Well, first off I think Lagerloff implied--at least I understood him to imply--that the Riverside epidemic was the result of reclaimed water and I think the record should be set clear on that. I don't think that point has been established at all. If it has it's news to me.

As I understand, in the Riverside area, all the normal coliform testing procedures seem to clear the water system in the first period of the epidemic. Then as the disease spread the reports seem to indicate that the water system or the water supply was the source of it. This merely points out that maybe there are deficiencies in the ability of present methods to determine whether your waste waters are capable of proper and efficient reuse.

Lagerloff:

Let me just make one point. The test that you presently make in the Whittier Narrows doesn't take into consideration, in my opinion anyway, the fact that ground water moves so slowly that you haven't had any real test of what there might be in the ground for future pollutant or contaminant possibility. The movement, as I say, is so slow, the amount of dilution so great, that if this recharge by use of waste water were on a much larger basis, what would develop? There are so many things that are involved in this that, as I say, let's assess the gamble and consider the possibilities.

McGauhey:

Implicit in Frank Stead's statement about standards is the inadequacy of standards and the fact they may be obsolete. Perhaps we are looking for the wrong thing. It is somewhat like hunting; while you're hunting elephants the tiger creeps up behind you and pulls you down. In many of our standard tests we have been looking for elephants without knowing there were tigers about. It's possible that this concept is implicit in this particular question of ground water quality.

Frank, you want to speak to this point?

Stead:

I'd like to make just two points, and I think your comment is a real contribution in pulling our thoughts in this direction. As I see it, the penalty one would pay for a mistake is that one must then treat ground water as we now treat surface waters in our major streams. The problem is no worse, but still serious. From a public health viewpoint, or from the concern of the Health Department, one of the greatest penalties of this shift would be that one would have to degrade the potability of water by chlorination. When one chlorinates and puts marginally chlorinated water into a distribution system, there can be no question that one has degraded the potability of water, but it is not a catastrophic long-range, decade-long phenomenon that produces that kind of results. Your second point was, "Are we testing for the right things?" I alluded earlier to the fact that when you set up a new situation, a new phenomenon in the environment that never before existed under the so-called natural state, then you can't monitor in the regular way. That is, in the regular way we monitor air, water, and so forth, by saying we know how the system works, we know what is there, and we choose a convenient handle to monitor. When you're dealing with a new situation, you must do descriptive monitoring, not index monitoring, and if this was the context of your criticism or comment, it's one that I consider extremely valid. When one sets up a new state of affairs, the job of monitoring is multiplied manyfold, and we're not doing this kind of descriptive monitoring of looking for the tigers that may be there.

Inerfield:

We might reflect a little on the plight of the Mississippi Valley, if one wishes to look at a water system. The cities along the Mississippi have to take water out of the wastes that have been discharged from the cities upstream. This whole business of how you manage and how you treat water so that it can be reused is something that we're living with the Nation over. But over and above this fact, the fact that we're faced with water problems, I think that there is an important public image to use water constructively, to use it over and over again as many times as we can, when we begin to look at the problem that faces us with transport of new water into this area. We recently returned from a conference in Corvallis where we were talking with the people of Idaho and Oregon and the northern states, and here the one question that was often repeated was: What are you doing about trying to make better use of the water you already have before you start raising the question of transporting more water into the area? They think that it should be perfectly obvious to us that if we look at the total water problem that confronts us in the future, we have to make every effort that we can constructively to go ahead to make use of the water in the most beneficial way. Certainly I think Frank Stead has outlined that we proceed in this way with great caution and with real understanding of what the systems are that we're working with. I think we're getting down to the point where we are being pretty idealistic about a system if we say we always want to use water that has never been used before; this can never be the state of affairs in this country that we have today. We're going to have to reuse water and it's a matter of getting the water quality to a point where we're sure that we can reuse it and make beneficial use of it.

McGauhey:

Jack, do you want to make a comment?

McKee:

Mr. Lagerloff made a very good point and I think we ought to emphasize this again; namely, that ground water normally moves very, very slowly. In a typical situation in the Santa Ana basin, or in the San Gabriel basin, water moves about a half a foot a day; that means 180 feet in a year, and that isn't very far. True, his point is correct that if a pollutant is put into ground water it may be ten years before we discover it at a well downstream. For that reason we have to be very positive about what is used for ground water recharge. If we're going to recharge with a highly saline solution or with borate or something of this sort, we've got to face the fact that those things are going into the ground and are going to show up eventually in a well. But if a well-treated, highly monitored waste water, of which we know the characteristics, is put into the ground, and if that water is good enough before it goes into the ground that we don't have to worry about it, then this time factor is all in our favor. As a matter of fact, if it does take three or four years for the water to get from the Whittier Narrows spreading grounds down to some wells downstream, don't forget that in those three or four years any possible pathogens are sure to die off because they're in an unfavorable environment where we know they die off rapidly. Secondly, the water comes into equilibrium with the soil, and this is a relatively slow process with regard to the calcium and magnesium and sodium content and so on. The water then gets a better chance in effect to purify itself. So this time factor is all in our favor.

McGauhey:

One final question or comment before we close this session of our program.

Member of Audience:

You said in effect that the Office of Saline Water was interested only in desalinizing oceanic water. This is the splashy part of their operation which catches national and newspaper attention of course. But they are interested also in desalinizing water of lesser mineral content. They are supporting researches, you know, in reverse osmosis and electrodialysis. Both processes are not well adapted to waters of very high mineral content. Further, they recently asked us of Geological Survey if we could turn up for them some sources of water that produce reliably 1,000 gallons a minute with a concentration of total dissolved solids around 5,000 ppm. So if any of you know of any sources of that nature I'd like to hear about them.

McGauhey:

Thank you for putting the record straight. The point I was trying to make, not in criticism of the Office, is that I think it would be well as a national policy, deliberately to expand the scope of the activities of the Office so that getting water from anywhere is one of

the major objectives of national policy invested in this particular organization. I should like to see more activity in, for example, the desalination of irrigation return waters to recover water for further irrigation and other beneficial uses at the highest possible potential, thus making less necessary our attempts to reclaim ocean water.

L-1

HOW DO WE MEET NEEDS AND ACCELERATE ACTION?

Moderator: P. H. McGauhey
Chairman, Department of Civil Engineering
University of California, Berkeley

Harvey O. Banks, President, Leeds, Hill, and Jewett, Inc., Consulting Engineers, San Francisco

James H. Krieger, Best, Best, and Krieger, Attorneys at Law, Riverside

Warren A. Hall, Director, Water Resources Center, University of California, Los Angeles

John D. Parkhurst, Chief Engineer and Manager, County Sanitation Districts of Los Angeles County

Lloyd C. Fowler, Chief Engineer, Santa Clara County Flood Control District, San Jose

James F. Sorensen, Consulting Civil Engineer, Visalia, and Member Board of Directors, National Reclamation Association

McGauhey:

Mr. Chairman. I might start off this final panel discussion by calling attention to the fact that it consists primarily of the chairmen of various panels which have appeared on the program. Some of these panels posed questions which I am not sure ever got answered. I want to see whether the panel chairman and the audience think they got any answers. We also have on this panel others who gave leading talks and who accused us all of being very remiss in some of our activities. Perhaps they have relented and now have some ideas as to what we might do. Mr. Banks falls in this class. He notes a very vast failure in comprehensive planning; and certainly there is such a failure. Mr. Porter stressed the need for getting public support for legislation and timing of proposed legislation if even the best engineering proposals are to result in any kind of action. Unfortunately Mr. Porter found it necessary to leave earlier today.

Mr. Fowler led a panel which called attention to the need for data and for interpretations of data which are not being met at this point of time even though DWR is spending a third of its appropriation on this particular activity. Mr. Hall's panel gave us some irreversible shock this morning, and I want to see if the four or five areas which he thought needed some attention can now be clarified some for the future. Mr. Krieger, as you know, came up with three questions and I want now to see if the results of his panel's deliberations or his own thinking can answer any of those questions. If we can get some answers to these, we shall certainly be on the way to fulfilling the purpose of

this particular panel: To suggest "how we meet needs and accelerate action." The panel you have just heard left unanswered the question of how legally we should deal with the matter of standards. I have asked panel member Parkhurst, who is also a member of the President's Advisory Board on Water Pollution Control, to speak to this point.

I will call first on Harvey Banks and then on Jim Krieger to look a bit into the future for us.

Banks:

The future probably won't be much different than the present, but there is always some reason for hope.

The first Session of the 89th Congress has passed the Water Resources Planning Act of 1965, which has already been signed by the President. Under the Act, there will be a Water Resources Council consisting primarily of the secretaries of those federal departments active in the field of water resource development. It authorizes the formation of river basin or regional commissions to coordinate planning in an advisory capacity. In my opinion, the Act does not go far enough, but at least it is a start in the right direction. I hope that we professionals and laymen concerned can in some way convince the Water Resources Council that it must use its best efforts to achieve sound planning at the federal level. This cannot be accomplished merely by dividing up projects and programs among the departments and telling each other what a good job each department is doing. This will need, I am sure, aggressive support from water people throughout the country. Otherwise, the Council may degenerate into just another committee at the federal level. As far as the river basin commissions are concerned, of course, it is the responsibility of the governors of the states concerned to make recommendations to the President for organization and membership. We should insist that, in the critical river basins or critical regions, river basin commissions be activated and that they take a positive and comprehensive role in water resource planning. It is extremely important that qualified and experienced people are appointed to the river basin commissions. The commissions must insure that the planning agencies give full consideration to ground water, its use, its management, and the full exploitation of its potential. It is our responsibility to make our views on these matters known to the Governor and to the commissions when activated.

Overall in the field of planning, we need a lot more research and the development of some new concepts. This is where the Water Resources Act will be important. Warren Hall and the UC Water Resources Center are doing an excellent job. But research in the social sciences as they relate to water development--particularly economics, public administration, the law, political science, and the like--must be expedited. Entirely new concepts are needed in this whole field of planning. We must look to the universities to develop most of those basic concepts for us.

In most states, the state agencies do not have adequate funds to do the job of planning that should be done. Here in California, the Legislature has always been quite liberal and has adequately provided for the planning effort at the State level. This is not true in most, if not all, the other 49 states.

There is a big job of education of both the layman and politicians to be done. We need drastic reorientation of our thinking with respect to ground water, for instance. We hear people and local agencies speak continually of "our ground water basin." A ground water basin doesn't belong to anybody particularly. This is an institutional attitude that must be overcome if best use of these resources is to be made. I am not referring to rights to the use of ground water, but rather to the total resource including the underground storage capacity.

Finally, there is a very definite need for the professions--the engineers, lawyers, economists, geographers, and the others concerned--to quit talking to themselves and to make their views and their recommendations known, in understandable language, to the people and their elected representatives who actually make the decisions as to what is to be done, when and where, in most cases in the field of water resource development. I would repeat that as professional people we spend entirely too much of our effort in communicating with ourselves and far too little in communicating our thoughts, our recommendations, and our criticisms to those who can really do something about it all. Thank you.

McGauhey:

Thank you, Harvey. I will now ask Jim Krieger to take over. Jim, when you have had your say, I would like you to rephrase the question that you put to my panel; then I will ask John Parkhurst to try to answer it.

Krieger:

I knew those questions would rise to haunt me. Let me answer the three questions first, and then I will pose the one that I put to your panel, Mack. The first question that I asked my panel was whether or not the rights of pump and use ground water was a valid property right or whether it should, under the exigency of our times, be given a lesser status than it now has. The answer that I would give to that question is, it is a valid property right and should be continued to be considered as such. It is so regarded in every stipulated judgment that I know anything about, or in any contested decree about which I know anything. Furthermore, it has been acknowledged by the Legislature in the enactment of the Water Replenishment District Act, where those people who have an adjudicated right are given a credit for that full amount of their adjudicated right before they have to pay for supplemental water. Second question that I asked the panel was whether the underground storage capacity that we have in our ground water basins belongs to anybody, and if so, to whom. And Bill Jennings launched on a splendid answer to that question and then left. And I talked with Bill before he left, and I think he would give much the same continuing response to that question as I would. It is my opinion that the Metropolitan Water District, for example, and there are other agencies that have the same powers in this regard, has the power to condemn underground storage. It could do the thing that Bill Jennings was

suggesting. That also raises the possibility that in order to get on with this show and not having to go through the tedious process of condemnation, that one might just go right ahead and use the underground storage capacity to store imported water, and let those who think they are injured bring suit in an inverse action. The reason for even suggesting that, and that's the kind of a suggestion a lawyer very seldom makes, is this: that it is extremely difficult to conceive of anybody being injured by storing water under the surface of his land, provided of course it doesn't interfere with any of his activities on the surface. And that is of course what I am assuming. Indeed, it might so happen that the use of an underground basin would raise the water level sufficiently to decrease the cost of pumping to the overlying owner, and you might have an offset of benefits against possible damages to the overlying landowner.

Third, I asked a question, what would be the best way to tackle the question of integrated agencies in this whole vast program of ground water management. And that question is by far the most difficult of the three and in my opinion is one of the things that we should consider here as a means of accelerating action, because until we know the kind of institutions that are going to do the job we need to have done, we're going to be very slow in getting those jobs done. Now, if you can visualize, as I am sure most of you can, literally tens of thousands of individual pumpers in the State of California over your ground water basin--mutual water companies and public utilities and public agencies of one kind or another--actually pumping local ground water and distributing it and doing nothing more. These agencies are under the control either of nobody, if they are individuals, or under the corporation commissioner if there are mutual water companies or under the Public Utilities Commission if they are a public utility. Then if you add to these the Metropolitan Water District contracting with the Secretary of the Interior for another source of water, you have another jurisdictional control. Then, if you add a contract between metropolitan and other agencies with the State of California for Feather River Project water, you begin to see the vast complexity of the relationships with which we are dealing.

Now if we take a side view of the question I asked the preceding panel, which is, "what do you think of the administrative setup to establish water quality objectives; and particularly what do you think of enforcement of those objectives," you suddenly see a whole new vertical structure here, because you have the local Regional Water Quality Board, and you have the State Water Quality Board, and then you have the Department of Water Resources that is interested in this matter; and to some extent again you have the Bureau of Reclamation and the Corps of Engineers interested in this problem. I suggested in my opening remarks this morning that unless the local agencies, so jealous of their power to do what they think is right, do something about the exercise of those powers, there is only one answer to the dilemma, and that is for the Department of Water Resources, which says it doesn't want to do it (and I'm sure it doesn't want to), to get into this business. They will simply have to do it. In other words, unless we can enlarge the powers of existing agencies so as to enable us to achieve the whole sweep of activities that are indicated, or unless we can take the powers we have and through joint power agreements cooperate

so as to get done basin-wide jobs that are under the control of various entities, we are going to leave a void so big and so urgent that somebody else is going to have to fill it and we are going to lose this precious gift of local control. So when we speak of accelerating action, it seems to me that the thing we need foremost in this picture is a legislative determination soon, of who is going to run the show.

The word "management" is one of my pet peeves. It is like "motherhood," "equitable," "honest," and all the other words that mean nothing until you put substance into them. The word management as we now use it means no more than the exercise of the powers of a particular local agency in the field in which it chooses to act. For example, there is no local agency that can manage a ground water basin in its biggest sense because it has no control over pumping; that is a court's decision to make. That is just one example of how empty the term management can be. So I think we are really on the verge of having to make that decision and seriously considering, for example, in the Metropolitan Water District, whether that big district wants to go into the business of storing water underground for its member agencies. That is a matter that I think should be taken up before the legislative bodies and before Carley Porter's committee when it starts these hearings very shortly.

I've summarized my views perhaps more lengthily than I should have, Mack, but I wanted to make that suggestion. Now may I direct my question to John Parkhurst. What do you really think, John, about the status of establishing water quality standards in the State of California, the division of responsibility, and perhaps some weaknesses in the field of law enforcement or water quality enforcement as things now stand?

Parkhurst:

That is a big question, Jim. There are a couple of axioms that I have heard many times and I think are appropriate here. One is--"we are making some progress but I'm not sure in which direction." The other axiom is--"there are two things you can't get out of water--one is salt and the other is politics." We are getting a little bit of the salt out nowadays but we still have a lot of politics. I'm saying this really sincerely because as you know this session of the Congress has been fighting now, and I use the word advisedly, for the better part of the session, over two different bills which are before the Congress, one by the Representative Blatnick and one by Senator Muskie. One provides that the federal government, under the auspices of the secretary of HEW, will have jurisdiction over setting standards on a national basis. Under the other the states will retain the right to set standards, at least for a period of two years. If the state fails to set quality standards, then the federal government can move in. Now one essentially is a states rights bill and the other is more of a federal type bill. We know that the President favors quite strongly the stronger bill that has been authored by Senator Muskie. The conferees have been fighting back and forth across the conference table

for several months; they still don't have a bill and my informants tell me that the possibilities of getting one at this session of the Congress grows more dim every day. Thus on the highest level in the country we can't agree as to where these standards should be set. I think more importantly though is, they are at least at the conference table and the issue is joined. Out of this rather historic meeting there will be some decisions made as to whom should set the standards; who should have the responsibility. If states set the standards I think we will probably find that they will establish them on a more statewide basis or even on a regional basis, but I think the trend is to establish such controls at an upper level rather than at a lower level. On this point, of course we get back into politics and the question of local autonomy; to the rights of a man to make his own decision whether or not to pump water and whether or not he owns the water below his property. This is all a very complex matter but I believe that the trend today is to look at the overall welfare and to protect water quality in the nation, in the state, and finally on a local basis. And so I rather believe that before the battle is finally won we will see some more give and take, but I think that ultimately we will probably have a rather strong bill, and a law. As a result of that we will probably have the control shifted into the new agency that is established under the bill; the Water Pollution Control Agency will have a new administrator and will be a separate section under an Assistant Secretary of the Department of Health, Education, and Welfare. This again is the trend of our times. Emphasis is being put on this very important problem of water quality and it's being put by the Congress and by the President. I think progress is being made even though we think that we are vascil-lating and fighting over who is going to set these standards. My feeling is that it will be more on a regional or a national basis. Certainly the individual basins will be taken into consideration, but I think the ground water will be protected, and I think this is exactly what we need.

McGauhey:

John, I have no idea whether that answers Mr. Krieger's question or not, but we shall perhaps have an opportunity for a little more exchange within the panel and between the panel and the audience in a very few moments. I am going to call now on Dr. Hall to see if he can reverse some of those irreversible things he talked about this morning.

Hall:

I am glad we have a lot of time left this afternoon. I have only got about four points to cover and it would only take me an hour and a half to cover each one of them. But I have limited myself to two cards of notes so maybe we can keep it just a little bit short. I think that our panel on economics this morning, if it did nothing else, certainly should have convinced you that it is a lot easier to criticize the current situation and tell somebody what's wrong with it than it is to come up with the panacea solutions which will get us out of the doldrums. But one of the most discouraging things about the whole matter, when you stop to think in terms of these irreversibilities, is

that failure to do something can also be irreversible, that it can get you caught as, for example, the New England eastern area has been caught with its present drought. By simply avoiding a problem over many years it comes home with a vengeance.

I would like also to comment on the question as to where responsibility and authority should lie for management of ground water, management of water quality, and so on. I have a pet theory that I proceed to expound on everytime somebody gives me a microphone. When I was in the Naval Reserve, I was given a job of teaching a class on labor relations. Being a person who feels he ought to be fairminded even though he isn't, I tried to find as much about all points of view as I could. I studied it very carefully, and when I came through I had only one real lesson to convey: that is, that people who duck their responsibilities soon have their responsibilities legislated for them. Now, in handling water quality and managing ground water, certainly one cannot say that the single individual is at fault. If every individual could live up to his responsibilities in every sense of the word in an economic sense, then you would have no reason to have any laws whatsoever. We have laws because individuals either will not or cannot economically discharge their responsibilities. So essentially we have to move up the ladder. However, in my judgment the highest level of government is probably self government, meaning the individual, and the lowest level of government is when you finally have to appeal to the final authority of the Supreme Court or the Congress to settle your problem. Now, my personal bias in this is that somewhere fairly far up on my scheme of levels of government, that is close to the individuals, you will find the solution which will be the best and will solve the problem to the best benefit of all the people that will be concerned with it. This is where it should be done.

Now at what level it will finally be done will really depend upon the ability of the people to take necessary steps and discharge their responsibility. If they accept the challenge and say that this is our problem and we are going to solve it, then indeed I think that in the long run the Congress will let them solve it, the state will let them solve it, or such other lower level of government as might be appealed to will be quite willing not to be involved in an otherwise nasty dispute. But where we bicker among ourselves, where we try to do what Adam Abruzzi called "maximize our purposive behavior," in other words, beat the system instead of living up to our responsibilities as management did in the problems of labor management at the turn of the century, then laws will be passed which will not be what you would want and will not be optimal for your particular unit. It will not be the best solution from your point of view. It will be a generalized solution which must also apply to other areas where the problems are not the same and as the ones you know. The old, what we used to call the knuckle skinning wrench was very universal, it would fit all the bolts that we had to take apart, but whenever you went to take one apart the first thing this particular wrench did was open up and take all the skin off your knuckles. This is precisely the kind of solution we will get if we cannot learn to identify our responsibilities and carry them out.

Now to add something more to what Harvey Banks said. He noted the problem of communications between the experts in water, and I might add, between the experts and the general public. Here I think, as far as an action program is concerned, two things have to occur. The engineers have to stop talking to engineers and patting each other on the back and suggesting that we are all right and the economists and the political scientists and everybody else are all wrong. All of us are going to have to pay attention to what the other person has to offer, understand it first and then debate it. I don't think that any of us have the answers in our hip pocket. This will have to be debated and it will have to be debated publicly so that the final decision makers, our legislators, our people, our representatives can make a decision. However, universities can play an important role in this. I think our Western Interstate Water Conference held at Las Vegas a year ago and at Corvallis this year, are indicative of the need for discussion. The expressions that have come back to me from people who attended those conferences of how useful the conferences have been to them, convince me that the public certainly can listen and will listen, and will listen with discrimination, if the point of view is clearly presented and discussed. In this connection, I think that we will have to avoid what perhaps we may have been guilty of in this particular program, and that is trying to cover too much in one meeting and wind up again and again scratching the surface a la the Egyptian hoe rather than getting in there with a good subsoiler and really make a mix which will grow the crops that we want to grow.

So I think that perhaps public conferences should get a little bit more deeply into the questions. My panel, for example, probably raised far more questions than we answered. But we need to answer these questions and the way to do it is to get people who have opinions about them, people who have done research and people who are doing research, to try to defend points of view and present these things in a language that can be understood. Now here again I am going to have to chide myself and all my colleagues that in the academic world it has become fashionable to develop a jargon to cover your particular discipline. There are several advantages to it. One is that when your promotion committee considers you for advancement it is not clear to them what you have been doing and therefore it must be very difficult, whereas if they can understand what you have been doing and they are not even in your field then obviously it is not very tough at all. And so you are not a satisfactory member of the academic community. We have to get rid of this approach; we all have to learn to speak the same language if we are going to make decisions that are compatible. I don't know how we are going to accomplish this in the long run, but those of you who are in the audience who are still in this academic community will, I hope, help us to accomplish this.

As I have listened to our discussions one of the problems that has consistently plagued me in trying to reason from the talks on to a solution, is that I'm really not clear as to what our objectives in the water business are. I think this is a basic question of policy that has to be taken care of very soon. For example, at the Corvallis meeting, one of our speakers made a strong pitch for what I would call the resources allocation point of view. In other words, the use of the

market place pricing as a mechanism for allocation of a scarce resource. You can come to a large number of conclusions by starting from the premise that we don't have enough water for everybody, ergo, we must learn how to allocate it to those people who can make the best use of it. Another thing that you can look at is the fact that virtually all the water that is delivered to an actual consumer goes through some sort of a public body or another which is a utility in nature, very similar to an electric light company. And one of the basic principles that a utility immediately faces when it gets into business, is that it can't discontinue service to a customer just because it doesn't know how it is going to get the resources it is supposed to deliver. I recall a case in Iowa where a poor old farmer made the mistake of letting his neighbors tie into his well because the water was of good quality. His widow found herself operating a public utility and when she tried to discontinue the arrangement, the courts would not let her do so. So this question of whether or not we can use resource allocation methods when we have these utility responsibilities, leads you to another entirely different point of view, that as a utility we must provide the water whatever the cost. The only thing we can do is say that the cost must be recovered.

The third thing that I deliberately brought out in the discussion, because I think that our whole water policy has to be carefully reexamined in terms of the 1965 to 2000 period rather than 1865 to 1950, is the old question of what is to be our national policy with respect to water use. I called attention to the 160-acre limitation and the question of subsidy. Let me make one brief digression here. I think that subsidy is probably the word which is going to cause the greatest obstacle that we have to progress in solving water problems. The reason for this is that we use the word both in the academic sense that you will find in Webster, that is, a payment by a government, usually, to someone for value received, and in the derogatory sense which implies that somebody is getting something for which they are not required to deliver anything in return--that the taxpayers are being defrauded. In general the sooner we can get this knocked off the better we will be. I admit that some of the latter occurs. Don't get me wrong. But I think we have to learn to distinguish between this improper subsidy which simply represents somebody's past political strength and avoid mixing that with subsidy which is payment for that which we get value in return. I have heard no one who is arguing for full pricing of water who is, also in the same breath, advocating letting the size of farms reach its optimal economic limit. Most of them want both full pricing and acreage limitation.

Those are just a few of the comments that I would like to toss out to the people here about economics in general and about the problems of where do we go from here.

McGauhey:

Thank you, Warren. Yesterday Mr. Fowler's panel talked about the status and needs in ground water development and management and I would like to call on him now to tell us a bit about what he thinks we might do in the future to meet the needs that were brought to our attention yesterday.

Fowler:

That request presents a real challenge, one that is probably one of the basic themes of this conference. It is apparent that we need to improve our present concepts and add new ones in order to fully develop the potential of our ground water basins and to efficiently integrate them with surface water supplies through effective management.

In order to make the improved and new concepts acceptable we need great amounts of data to demonstrate to everyone that we can solve the problems that appear to face us today. No development or management of water resources can be effective without utilization of large amounts of intelligible data. This requires long term data, information gathered in advance of the need. Therefore, it is essential that we plan for data. We can advance the programs of ground water basin management by starting to gather now the data needed in the future to evaluate the best type of integrated management. The answers obtained then can only be as good as the information fed into the equations.

We are fortunate that geology, one of the most important facets of ground water basin development and water resources management, is more or less fixed. It does not change within short time intervals as hydrology does. However, it takes time to learn about the geology of the area, to express it in useable units for development and management. Here too, lead time is needed in planning investigations. Geology can be so complex that it is easy to get lost in the details, to never reach a conclusion. We must continue to develop the present trends toward macro-geology, useable with integrated planning concepts. The use of mathematical models and electronic computers to assist the geologist in learning more about the effects of underground structures and characteristics on ground water movement is one of these new trends which should be more fully developed.

Artificial recharge of the ground water reservoir is one aspect that can be adjusted to allow the development of the full potential of ground water basins, but this tool is still in its infancy as far as management of our resources is concerned. Artificial recharge is expensive and must be considered as a management tool in the full light of all resources. Spreading ponds may take large land areas from other uses and in the terms of today's resources we must make the most efficient use of land. Unfortunately, multipurpose use of recharge ponds does not appear feasible. We need to continue to study the potentials of ground water recharge as a management tool including the problems created by biological nuisances by the cost of operation, by the

change in rate of percolation over time, and by the need to change location to fit the development pattern.

We need to develop criteria for water reuse and to be prepared to utilize the quality of water as a method of effectuating improved water resources management. One of the major criteria problems is the disposal of wastes from interior basins so that the total water resources are effectively maintained in useable fashion, so that the downstream basins are not adversely affected. Here again we need new concepts that will protect the water resources quality and yet allow the use of the very important waste assimilative capacity. Mathematical models can be effectively used to determine water quality changes with advancing use quantifying aspects that before were only crudely qualitatively discussed.

Above all we need to improve the economic evaluations of water resources management. There is a large need for more quantitative economic data on operational aspects. The old water quality standards are worthless for economic analysis, but present work to improve these concepts promise great things for economical management. We also must provide an understanding of the uneconomic aspects of water resources problems as well as the economic aspects to answer the questions of "why do it now?" or "why do it at all?" The standard use of the benefit-cost ratio as a basis for economic comparison needs reevaluation. It appears that it should be used only in feasibility studies in conjunction with other methods such as the internal rate of return.

There is a vast need for further education in all fields of water resources management with appropriate translation into popular understandable terms for public absorption, even to the point where members of the various technical disciplines involved understand each other. As Senator Cobey said the other day, you are not going to get the legislation you need to manage ground water basins or water resources until the public is receptive to and desire the proposals. This is a very real challenge to the processes of education. It appears that we will be in these processes for a long time.

McGauhey:

Thank you, Lloyd. To close out our formal presentations, I would like now to call on Mr. Sorenson to see what he can do to lead us out of the wilderness, how we are going to meet the needs to accelerate action programs.

Sorenson:

I don't really feel we have had today much indicated interest on behalf of the irrigator. It seems to me that maybe we are not giving credit to some, or credit for some of the things that have been done. It isn't very many years ago that the talk of even reclaiming sewage water at the level we talk about now could not even have been carried out. Certainly through all of these efforts that have been described here we've gotten to that point.

Another thing I think I ought to note. You heard some talk about subsidies and Warren Hall got over into the question of acreage limitation. This becomes quite a problem and it is not to be casually tossed aside, and I would here note the fact that acreage limitation comes into the matter of the use of federal water. I think we can look at the San Joaquin Valley situation and think a little bit about ground water recharge, the use of water, and the conjunctive use both surface applied and ground water reservoir and recharge. In this connection there have been for years some problems having to do with the use of ground water or the use of supplies which might have been recharged, let's say through a federal reclamation project. Action on these has lain dormant for some years but I am sure in my own mind that we shall soon have to face these problems. I think this is one of the factors which Dr. Hall may not have had in mind when he mentioned acreage limitation. His frame of reference was more of subsidies, but I think that the use of recharged ground water supplies is one of the political problems that we should probably be considering.

It seems to me that Jim Krieger put a lot of emphasis on master districts. I choose to call them master districts, let's say master agencies or some such. I think we have to look very very closely at master agencies. It is a pretty short step from our thinking about master agencies to the question of who or what or how is the master agency controlled. Who makes the decisions? And I would have to say that it seems to me that there is a problem or an area of concern, lest we penalize someone, some district, or some organization which has husbanded properly or well managed a resource. I must admit I could not help but think of that this morning when there were some comments about Howard Crooks' operations and some indication that if water got scarce maybe the Orange County people should lay off of the surface supply and let it move on to someone else. I think this probably has to come about, but I can't help but feel that there is a feeling there that they have more water than they need today. I am not trying to be specific as far

as that particular area is concerned, but I think when we talk about master districts, or master agencies, we must give this problem of control very close scrutiny. I think at the same time that we must assert some local responsibility. This is like being against sin probably everybody here would agree. If we are going to talk about management of ground water without the use of master agencies with the idea of local responsibility, we have to assert more local responsibility, more local ingenuity, and take this matter completely in hand. This would come down to a problem of cost versus benefit, and I believe it is going to behoove every one of our areas or districts to try to look forward 10 or 20 years to the situation that is going to exist at that time. Undoubtedly, as our water quality problems--I hesitate to use the word--worsen, as they become more acute, we have to have better education. It seems to me that one of our great problems is that of reaching out with some kind of information, maybe it's comic books adaptations, to reach the people who at the present time are not paying very close, if in fact any, attention.

Let me close this making a plea for the acceptance of responsibility at the local level. I'm sure that this includes all of the ingredients, education, management, political sensibilities. It includes a very broad and general education of all of our people.

McGauhey:

Thank you, Mr. Sorenson. I'm going to now ask for some discussion from the audience. In ten minutes I will turn the microphone back to the presiding officer and we will then initiate our closing ceremony.

Hans Doe:

I'm one of the numerous directors of the Metropolitan Water District. I listened with a good deal of interest to the suggestion, first made I think by Mr. Jennings, followed up by Mr. Krieger and commented on by several other panelists, that perhaps the time had come when the Metropolitan Water District should get in to the direct use of underground basins. And I think that I would like to talk for just a second about what Metropolitan is now, and has been, doing in the way of replenishment in the use of those underground basins. Mr. Jennings pointed out that the Metropolitan gives a discount, maybe 30 or 35 per cent off the price of industrial municipal water, when that water is used for replenishment purposes. Now it is well known within the Metropolitan board and by the staff, that much of the water that is used for replenishment actually is put into the basin and then pumped out someplace else. But the fact is that the basin is in a very much better condition by reason of the fact that that water is put in. The justification for the reduction in price given to the agency that puts the water underground is this: the supply is interruptable, that is the lowest priority water that Metropolitan delivers, and at any time that other agencies of the Metropolitan need more water than the Metropolitan is able to supply, while supplying also the replenishment project, the replenishment project is cut off. So, in effect, Metropolitan has the benefit of that underground basin until such time as the supply is put back on the line for that underground basin. I think that this should

illustrate that by pure economic means, the Metropolitan is using the underground basins that are in fact managed by others in detail. And the member agencies of Metropolitan other than those who overlay the underground basin are satisfied that it is a good arrangement and that the discount is justified because of the benefits that we reap from it. We get the use, in other words, of that storage underground.

McGauhey:

Thank you. Since Mr. Jennings is not here I trust that this is a clarification rather than a question directed to any member of the panel. Does anyone in the panel want to comment or shall we simply accept this as an addition to our proceedings.

Member of Audience:

Mr. Chairman, I would like respectfully to disagree a little with my friend, Mr. Krieger, and agree more with Lloyd Fowler and Jim Sorensen. There is an old and perhaps trite but still true saying that where there is no vision the people perish. When I came here yesterday morning the first thing that I looked at was, who was here? Now you remember during these proceedings a lot was said about what has been accomplished in Orange County, and in the West Basin and the Central Basin. And I looked around and it seemed to me that they had the best representation, and I looked around for, without naming any names, the opposite areas, and I saw hardly anybody here from those areas. Now I happen to be one of those people that believe there is no magic in the master district or big government or whatever you want to call it. I happen to have served for 30 years on one of these master districts, the Metropolitan Water District, and I still believe that there is no magic in size. The thing is that we just happen to be lucky in those three districts that I mentioned. We had a lot of people and I know a number of them sacrificed their own interests. They spent time which they could very well have spent in advancing their own economic interests in order to put these programs across. Now my point of disagreeing with Jim Krieger is this: if you've got those kind of people, then the job of finding the mechanics by which you can accomplish it is not too difficult. You need the people first who are willing to do the job. If you don't have them you can't get it done anyway. You first have to have these people. When we started out in the Central Basin we knew almost immediately the kind of mechanics that we wanted to follow in order to accomplish this objective. The problem was accumulating enough strength to get it across. Now oddly enough, and I happen to be an editorial writer, I found that educating the public was not too difficult. The difficulty was in educating the water producers who held fast to these old concepts and who screamed "well, somebody's trying to steal our water," and the biggest job of all was educating them to get them to understand that when you were drawing down your basin and you didn't have enough water everybody had to participate in this thing on a percentage basis or else you didn't get anywhere. The public were not difficult to convince of the necessity of these measures. They could easily understand the thing that I have just said, that the water levels were going down and you couldn't do that forever. We did

not get very much argument from the public on that point of view, but we had to have the people who were willing to spend the time to get this program across, and we were just lucky we had them.

McGauhey:

Mr. Krieger, do you want to make a comment.

Krieger:

I would like to make this comment. Certainly I was misunderstood by Warren and certainly by Jim Sorenson, and anyone who thinks that I am an advocate of the master district. If I said that let me correct it, and I think Warren and Jim both know me well enough and know the article that we wrote on this subject and know that is not true. What I'm trying to say, Warren, and Jim particularly, is this: that unless you assume your responsibility as a local agency, which all of us up here have talked about, the very gift that you speak of so highly will pass out of your hands and somebody else will assert that power. I've tried to say in as nice a way as I can, that unless we in the local agencies find some way to store the water we've contracted for and to use the underground storage capacity, certainly the State of California or some other agency will do it for us, and I'm advocating against that position and I'm joining the people from the state in their position as it has been stated here today.

McGauhey:

Unfortunately it is now time to close the discussion. The possibility of us going away from here having given word to all of our ideas is remote. One of the problems of all of us is that we get charged up like a condenser and then we want to discharge our ideas. You can't just half discharge a condenser so there is a lot more to be said. For this reason we will probably have to have another conference in two years, and from what I have heard this afternoon I doubt that we are going to have much solved by then. At least it will be a good time for a new report or a new evaluation of our situation. So I am going to turn the microphone back to your presiding officer who will close the conference. Thank you on behalf of the panel, and thanks to the panel for appearing here this afternoon.

CLOSING REMARKS

John R. Teerink, Assistant Chief Engineer, California Department of Water Resources and Chairman of the second day of the Conference on Ground Water: "I think the interest displayed during the past two days and the fine presentations that were made, is evidence that a program such as this has real value. It has come a long way from the time that a few people who were interested in ground water recharge got together in Bakersfield and discussed some of these ideas. Leonard Schiff, the man who is responsible for putting together this program, the one who has shepherded it through the years, demands a lot of respect from us and a vote of thanks. I now turn the Conference back to our Program Chairman for concluding remarks."

Leonard Schiff: Senator James A. Cobey, Chairman, California Senate Fact Finding Committee on Water Resources, in his closing remarks has stated a major objective of this Conference. His objective plea for us to inform the public and with the public write into law fair solutions to problems should be read by all interested in the solution of our water problems.

On behalf of Sponsors and as Program Chairman, I again thank program speakers and all of you for the fine attendance, participation, and interest in this Conference. I am grateful to you for your cooperation and I again thank the many people from other states and countries who have come here to exchange ideas.

We wish to exchange ideas and help inform the public and press so that we can help those that make decisions and laws in the light of technical information as tempered by social and economic considerations from local to regional aspects.

I hope we leave here with ideas about additional approaches to meeting needs and accelerating action. I hope we can help prompt action programs based on mutual understanding.

I thank all of you very much. The fifth Biennial Conference on Ground Water is now adjourned.

In retrospect as I review the Proceedings I cannot overemphasize our theme which suggests that professional people in the various fields of ground water and other interested people get together and speak in understandable language and through mutual understanding, desire, and initiative develop action programs. Other interested people means individuals in local areas and those in Districts of various types. It means the public in general and the press. For all it means people representing local to regional opinions, opinions of individuals and agencies.

Your program chairman will look to you for suggestions and help. A number of people have spoken to me during the Conference about ideas for this Conference and offered to help. Ideas and help will be gratefully welcomed always. May I thank all of you again for your participation and your desire for an objective progressive conference directed toward the achievement of worthy goals.